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# AGRICULTURAL ENGINEERING

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# Pressures and Loads of Ear Corn in Cribs[1]

By J. R. McCalmont[2] and Wallace Ashby[3]

REPORTS OF FAILURES of large corncribs when filled rapidly and the need for experimental data on which to base satisfactory crib design caused the Division of Structures of the Bureau of Agricultural Engineering, U. S. Department of Agriculture, to make a study of the pressures exerted by ear corn on corncrib floors, walls, and cross-bracing.

An experimental corncrib 16 ft long, 24 ft high, and with a movable side which could be set to give widths from 8 to 12 ft, was erected for this purpose in 1931 on the Toledo Experiment Farm used by the Bureaus of Entomology and Agricultural Engineering, U. S. Department of Agriculture, for corn borer control experiments[4]. The floor of the crib was supported by 6-in steel I-beams spaced 2 ft on center. Steel I-beams were used as studs for the south wall. The corner and two intermediate studs on the south side were 7-in steel I-beams without truss rods. The remaining five intermediate studs were 3-in steel I-beams trussed with 1-in rods. The corner and two intermediate studs on the north side were 3x16-in fir, and the remaining five intermediate studs on the north side and the end studs were of 4x6-in pine reinforced with truss rods. The construction of the south side and west end of the crib is shown in Fig.1. One-by-four-in wood strips were bolted to the faces of the steel I-beams and 1x6-in crib slats were nailed on in the usual manner.

Arrangements were made to calculate the pressure on the crib walls and floors from the measured strains at selected points in the steel beams and truss rods. A Whittemore strain gage was secured for this purpose and all steel beams were prepared for strain readings at 2-ft intervals along their length.

The strain gage points are set in small holes bored in the outer face of the steel members. Changes in length of the steel members between gage points 10 in apart were measured to the nearest ten-thousandth of an inch by means of an Ames dial which is a part of the strain gage. Temperature changes were compensated for by reading a standard 10-in bar of mild steel laid beside the structural members while strain readings were taken. This method had been developed by the U. S. Bureau of Public Roads and the U. S. Bureau of Standards for studies of bridges and other large structures.

The crib was first set up at its 8-ft width and a complete set of readings taken before any loading was started. The difference between these zero readings and the standard bar of mild steel gave differentials between the standard 10-in gage length and the actual distance between the gage holes in the members. Any further changes between the standard 10-in gage and the gage lengths of the members were assumed to be due to loading.

The crib was filled four times in the fall of 1931, using a portable elevator. The corn weighed about 28 lb per cubic foot. The first filling was with the crib set for the 8-ft width without cross braces. A short 4x4-in hardwood post was set under each steel joint in line with the north wall to act as a foundation pier. These posts were supported by a broad concrete footing. Wedges were used to raise the joists free of the concrete wall at the north side, to give the joists an effective span of 102 in. Strain gage readings were taken on all steel members when the crib contained 8 ft of corn, and again when it had been filled to the 16 and 24-ft levels. The crib was then emptied and steel crosstie rods were placed at 4-ft intervals at the 8 and 16-ft levels. The crib was then refilled, strain gage readings being taken as described for the first filling.

The crib was again emptied, the wall was moved out to the 10-ft width and supported as before by short posts under the joists, and the crib was refilled with crossties in place. Strain gage readings on floor and wall members were taken as before. After the crib had been filled to the 24-ft level and strain measurements taken, the crossties were slacked off and a new set of readings taken for all points. After this the crib was emptied, the wall was moved to give a 12-ft width, crosstie rods were placed, and the crib was refilled. Strain gage readings were taken with 8 ft, 16 ft, and 20 ft of corn in the crib. The crosstie rods were then slacked and a set of strain gage readings taken for 20 ft of corn.

*Loads on Floor Beams.* Floor loads were calculated from the strain-gage readings taken at 2-ft intervals along the floor beams. Since the approximate moment at any point in a beam was a function of the strain recorded by the strain gage, it was found by the formula

$$M = \frac{d\,E\,I}{10\,c}$$

where $d$ = recorded deformation of 10-in length of member

$E$ = modulus of elasticity = 30,500,000 lb per square inch (by test)

$I$ = moment of inertia of section

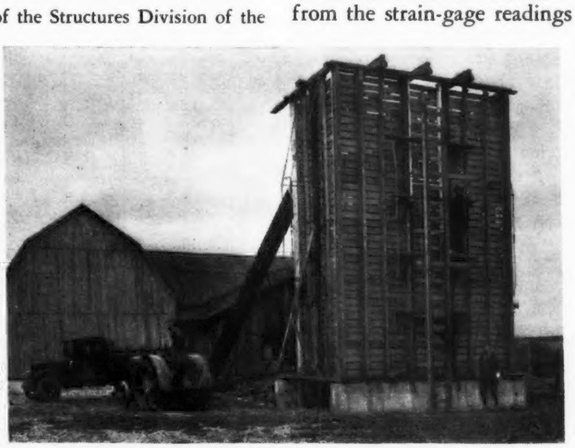


FIG. 1 EXPERIMENTAL CORN CRIB USED FOR MEASURING PRESSURES EXERTED BY EAR CORN, SHOWN HERE AT 8-FT WIDTH

[1]Paper presented at a meeting of the Structures Division of the American Society of Agricultural Engineers, at Chicago, December 1933.

[2]Division of Structures, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Affil. A.S.A.E.

[3]Chief, division of structures, Bureau of Agricultural Engineering, U. S. Department of Agriculture. Mem. A.S.A.E.

[4]Much assistance in carrying out this work was given by R. M. Merrill, I. F. Reed, A. H. Glaves, and other members of the Division of Mechanical Equipment, Bureau of Agricultural Engineering, U. S. Department of Agriculture, located at Toledo, Ohio.

[5]For suggestions on adequate cross-bracing, see U.S.D.A. Farmers' Bulletin 1701, "Corncribs for the Corn Belt."

$c$ = distance from neutral axis to outer fiber of beam.

While the moments could be calculated easily, there was some uncertainty about the amount and distribution of load on the floor. If the load were of "uniformly increasing to the center" type, its amount might be determined from the moment at the center of the beam by the formula.

$$M = \frac{W L}{6} \quad \text{or} \quad W = \frac{6 M}{L}$$

On the other hand, if the load were uniformly distributed, it might be determined from the moment at the center of the beam by the formula

$$W = \frac{8 M}{L}$$

Theoretically it is possible to determine the type of loading from the strain curves for the beam, but actually the difference between strain curves for uniformly distributed and uniformly increasing types of loading is less than the experimental errors. However, estimates of the load on the floor, made by deducting the loads carried by walls and cross bracing from the total weight of corn in the crib, indicated that the load on the floor closely resembled the "uniformly increasing to the center" type.

The curves in Fig. 2 show average floor loads on three center joists, assuming that the load on the beams increased uniformly to the centers; in other words, that $W = 6 M \div L$. The curve for the 8-ft crib without cross braces is based on work in both 1931 and 1932 and is believed to be approximately correct. The other curves are based on work in only one season.

The percentage of the total weight of corn carried by the floor in cribs of different heights is of interest. With 8 ft of corn in the 8-ft crib without cross braces, about 72 per cent of the load rested on the floor and about 28 per cent was supported by friction on the walls; when the depth of corn was increased to 16 ft, about 64 per cent of the weight rested on the floor and 36 per cent was supported by friction on the walls; and when the crib without cross braces was filled to the 24-ft depth, only about 52 per cent of the total weight rested on the floor and 48 per cent was carried by the friction on the walls. Another way of stating this is that the lower 8 ft of corn weighing nearly 1800 lb per foot length of crib resulted in a load on the floor of about 1300 lb per foot length of crib; the second 8 ft of corn increased the load on the floor by 1000 lb per foot of length of the crib, while the upper 8 ft of corn increased the load on the floor by only 500 lb per foot of length. From this it is seen that in high cribs a large part of the weight is supported by the walls. Apparently in wider cribs, a somewhat greater percentage of the weight is carried by the floor.

*Pressure on Walls.* Calculation of the pressures on the sides of the crib from the 1931 data proved to be much more difficult than had been expected. Stresses in the beams were complex and there were large variations in the strains recorded for similar members. After a study of these data it was concluded that the method had not been satisfactory for finding lateral pressures and that it would be necessary to find a more direct way.

FIG. 3 VIEW SHOWING POSITION AND CONSTRUCTION OF CORN CRIB PRESSURE PANELS

In the fall of 1932 the wall pressures in this corn crib were measured by a simpler method. The crib was set up at the 8-ft width, and openings approximately 3 ft 6 in wide and 24 ft high were made at the center of the north and south sides by removing the center stud and sawing off the cribbing slats. The studs at the sides of these openings were then stiffened so that they would deflect very little under the expected load of corn in the crib, and the wall was completed by setting six pressure panels each 4 ft high in the opening, as shown in Fig. 3.

Each panel was made of 1-6-in cribbing nailed to 2x4-in cross pieces bolted to 4-ft sections of 3-in I-beams. The panel was supported in place by $1\frac{1}{8}$-in heat-treated steel bars which passed through holes near the top and bottom of the I-beams, and, where wood studs were used, rested in steel brackets bolted to the studs at the side of the opening. Where steel sections were employed in the construction of the crib, the $1\frac{1}{8}$-in bars rested in $1\frac{1}{4}$-in holes in the webs of the 7-in I-beams used as studs. The $\frac{1}{8}$ in of play in the supports allowed the steel bars to come to good bearing at the four corners of the panels. Pressure against a panel caused deflection of the spring steel bars, and the amount of this deflection was a direct measure of the pressure on the panel. The panel was entirely free from the crib wall proper.

The deflections of the spring steel bars in both the horizontal and the vertical planes were measured by a special instrument built to read the deflection over an 18-in gage length. Deflections were read by means of an Ames dial to the nearest ten-thousandth of an inch, and readings could be repeated with an error of less than 5 ten-thousandths of an inch. Before the steel bars were set in place in the crib, they were calibrated in a standard testing machine at the mechanical engineering laboratory at the University of Toledo, bearing and support points being placed at the same distances as in the crib. It was found that a deflection of 1 ten-thousandth of an inch corresponded to a load of about 2 lb on the bar, the exact amount varying

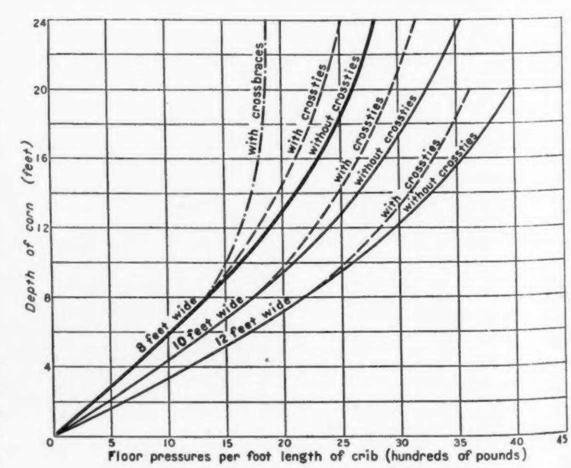



FIG. 2 WEIGHT OF CORN SUPPORTED BY THE FLOOR

slightly because the spacing of the panel parts was not exactly the same in all cases. Since the pressure area supported by a pair of bars was 12.67 sq ft on the north side of the crib and 14.0 sq ft on the south side, the accuracy of reading was to within about 1.5 lb per square foot.

The remodeled crib was filled first with no cross braces in place. The corn weighed about 26½ lb per cubic foot. Readings on the panels were taken when the crib was filled to the 4, 8, 12, 16, 20, and 22-ft levels. The crib was then allowed to stand for two days and a final set of readings were taken. It was then emptied and cross braces were set at 5 ft from either end of the crib. One set of cross braces[5] was built of four pieces 2x8 in and two pieces 2x6 in nailed on the uprights in pairs crossing at the center of the crib. The first planks were 6 ft above the floor at the side of the crib and 9 ft 6 in at the center. The second pair was 4 ft 4 in above the first and the third pair was 3 ft 2 in above the second. All planks were tied together by a vertical 2x6-in piece in the center. The second set of cross braces was like the first except that the upper pair of crossed planks was omitted, and the center tie ran to the top of the crib and was nailed to a crosspiece at the top. The 4x6-in posts supporting the cross braces were not nailed to the side of the crib but were left free so that the weight of corn resting on the cross braces could be measured. The posts passed through the floor and were supported on short 3-in I-beams. These I-beams, like the spring steel bars, were calibrated in the testing machine before being set in place, and their deflections were read with the same instrument.

After these modifications the crib was refilled and readings on the pressure panels and on the I-beams supporting the cross-bracing were taken as each 4-ft depth of corn was added. After loading, calibrated-beam readings were secured after the corn had settled one and two days, and at seven-day intervals for four weeks. A final set of readings was taken ten weeks after filling. It was not practicable to take strain gage readings during progress of the tests in the fall of 1932 because the only Ames dial available was in use on the deflection gage. Strain readings on all beams were secured as part of the final check after the crib had been filled ten weeks, but as in the case of the 1931-32 data, efforts to check these results with the data secured from the calibrated bars were not satisfactory and these data have been laid aside for the present.

The outward and downward average pressures on the crib walls at filling time as measured with the pressure panels are shown in Fig. 4. Values taken from these curves represent the downward and outward pressures per square foot of wall surface at a given height and should not be multiplied by height to find the total pressure per linear foot of crib. It will be noted that the maximum outward pressure in the 8-ft crib without cross-braces was about 100 lb per square foot, while in the crib with cross-braces it was about 90 lb per square foot. If the crib without cross-braces had been filled as rapidly as was the crib with cross-braces, the maximum pressure would doubtless have been higher. Pressures on the walls increased slightly for the first 24 hr after filling, then showed a variable but consistently decreasing trend. The ratio between the outward and downward pressures on the walls of the crib is the coefficient of friction. The average results of this test give 0.62 as the value of this coefficient.

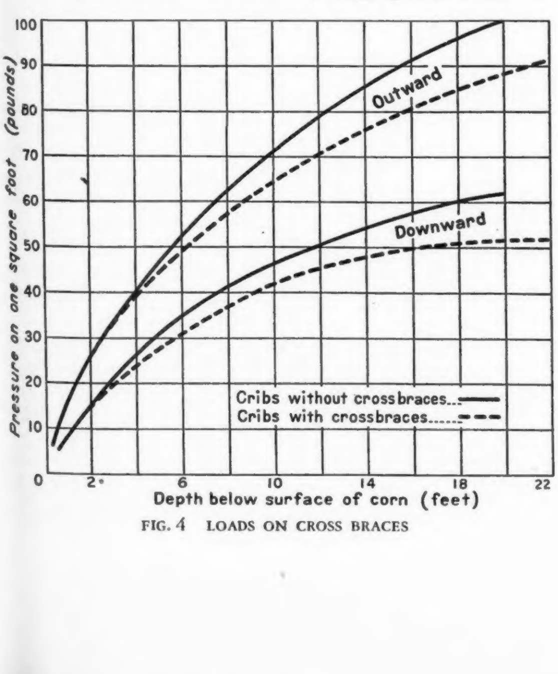



FIG. 4 LOADS ON CROSS BRACES

Measurements of side pressures on the 10-ft and 12-ft wide cribs in 1931 did not yield satisfactory results, as already noted, and there has been no opportunity as yet to make these measurements with the improved apparatus. It seems probable that the outward and downward pressures on the walls of 10-ft cribs are nearly 25 per cent greater, and in 12-ft cribs are nearly 50 per cent greater than those in the 8-ft crib.

*Loads on Cross Braces.* Fig. 5 shows graphically the loads carried by the cross braces of the 8-ft crib during the time of filling and for six weeks after.

These loads are of a special interest since they show that with 24 ft of corn in the crib about one-third of the total weight was carried by the cross braces after the corn had settled one week. This weight was sufficient to break down lightly constructed cross-bracing.

The loads on the cross braces gradually increased for three weeks after filling, apparently on account of the shrinkage of the corn below the braces, then gradually decreased as the corn continued to dry. On the other hand, after the second day the outward and downward pressures on the walls decreased rather uniformly as the corn dried out and shrank.

As already noted, in spite of the large portion of weight of corn carried by the cross braces, the side pressures on the panels of the crib with cross braces was almost as great as in the crib without them. Rate of filling may account in part for this apparent discrepancy, since the crib without braces was filled in eight days, and the crib with braces in three days, the longer period affording the corn more opportunity to settle and become stable.

In the 8-ft crib with cross-braces, when full, about 45 per cent of the weight of corn was carried by the floor, 20 per cent by friction on the walls, and about 35 per cent by the cross-bracing.

## CONCLUSIONS

These experiments indicate that the outward and downward pressures on the walls *(Continued on page 128)*

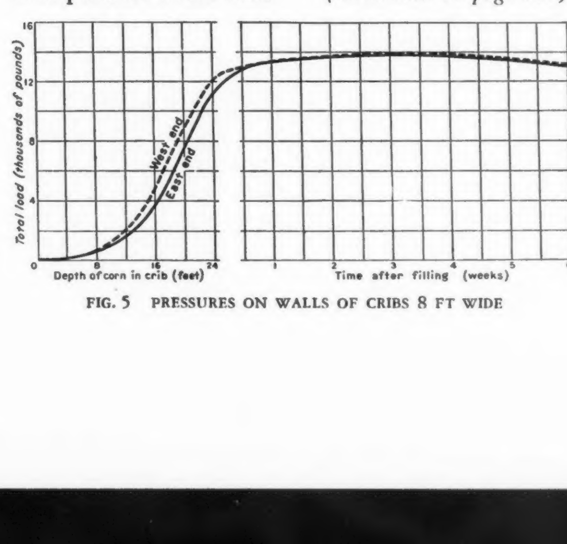



FIG. 5 PRESSURES ON WALLS OF CRIBS 8 FT WIDE

# High-Speed vs. Low-Speed Internal Combustion Engines[1]

By S. F. Evelyn[2]

A HORSEPOWER developed at 2000 rpm (revolutions per minute) can be bought and maintained for considerably less than the same horsepower produced at 1000 rpm. Similarly, the utility range of an engine designed for high speeds is much greater than that of an engine primarily intended to operate at a more or less fixed speed value of the lower order.

Knowing that the art has progressed to the point where high speeds do not present anywhere near the problems encountered in the earlier days, and that, if properly applied, high engine speeds give rise to far-reaching economies, we are impressed with the rather limited extent to which a prospective buyer can or will avail himself of the advantages, owing largely to a prejudice founded on a faulty conception of what speed really is.

What follows, therefore, deals principally with a truer and more helpful method of defining speed, rather than with the advantages or disadvantages of a so-called high-speed engine as compared with a low-speed engine, and vice versa. After all, the nature of the load is, or should be, the governing factor in fixing the choice. But it is common knowledge that much is being said against high speed, most of which is unjust if based on nothing more than engine "rpm."

This term ("rpm") usually is referred to as a speed, but aside from its value as a transmission factor whereby is determined the relation of a load to its prime mover, "rpm" states only one thing, and that is the frequency with which certain engine cycles are repeated in a given time. In a gas engine there is a variety of speeds: piston speeds, rubbing speeds, gas speeds, etc. Connected with pressure they become significant in the measurement of power and the conditions under which it is produced. Due to varying proportions used in the design of an engine, there is no absolutely fixed relation between rpm and the other speeds. A 5x6 engine operating at 900 rpm does so with a piston speed of 900 fpm (feet per minute), while a 4¼x4½ engine of equal power at 1800 rpm has a piston speed of 1350 fpm. Rpm has been doubled, but piston speed was increased by only 50 per cent. Similarly, the rubbing speed of the main bearings, instead of being doubled, was raised only 60 per cent. The latter figure applies to a crankshaft relatively equal to that of the large engine; that is to say, torsional and transverse rigidity as well as the bearings are the same in proportion to load.

Speed being associated with wear, it is rather unfortunate that, on the buyer's side of the argument, "rpm" assumes so important a position; for in his judgment of the two engines he is very apt to conclude that the small engine will last only half as long because it runs twice as fast. Viewed from this angle, rpm in itself—unqualified by factors which might give to the term a more inclusive meaning—is of little value in gaging whether or not an engine will measure up to accepted standards of service. In fact, comparisons based on the usual interpretation greatly complicate the issues when engines of different size and design are involved. But it would be unwise even to attempt substitution of another, though possibly more valid, designation. For one thing, it is no easy matter to change a mental habit; for another, it is equally difficult, if not impossible, to find a single term that will express so much once a method is adopted that will make rpm as communicative of the engine's speed characteristics as its power rating is in relation to the load it can carry.

Somewhat loosely, but acceptably in the main, it may be stated that for any particular engine the maximum combustion pressure remains fairly constant, therefore independent of rpm. On the other hand, the inertia pressure of its major reciprocating parts will rise and fall in unison with rpm. It is hardly necessary to point out that from the standpoint of wear and tear combustion and inertia take the lead, and that principal engine parts must be proportioned to withstand the maximum load of combustion, if nothing else, regardless of how low rpm may be taken. Consequently, if for any engine there is established an rpm value at which the maximum inertia pressure equals that of combustion, it may be said that a practical limit of bearing capacity is reached. Although in practice load computations are more complex, taking into account the magnitude and direction of combined inertia, combustion, and centrifugal pressures throughout the cycle, the two maximum values only were here retained because they are inherently representative and quite simple in their calculation.

Further, it develops that to find the answer, characteristic values of design must be employed, which involves the bore, the stroke, length of connecting rod, compression ratio, and—to a certain extent—the basic idea of design as expressed by the reciprocating weight in regard to the bore. Stated in this manner rpm is qualified to serve as a reliable guide in a classification wherein it should preside as the engine's high speed; but not maximum speed as will appear later. Proceeding on the assertion that a critical point in engine performance is reached when a parasitic force of the first magnitude achieves the proportions of the useful force, and keeping in mind the law whereby the former increases as the square of the increase in rpm, it may be inferred that beyond this point any gain leaves no doubt as to the designer's intention that speed is to be the predominating factor. Practice has proved this. Analysis by the suggested method of a number of engines on the market showed that peak power took place at varying percentages below and, in some cases above, the high speed figure; but in no instance was it attained or exceeded until specifications were subordinated to it.

As stated before, high speed should not be confused with maximum speed, for the latter represents an entirely different set of conditions. It is the absolute limit of engine performance, taking place when the power absorbed by the engine is equal to the power produced by it. With proper precautions maximum speed may be employed as a comparative measure of efficiency, by reference to high speed, whereas peak power speed expressed in percentage of high

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December 1933.

[2]Consulting automotive engineer, Detroit.

speed may be taken as indicative of the extent to which speed characteristics are embodied in the design.

Far too much blame is thrown at the feet of speed. When properly compensated for, normal engine wear proceeds at a surprisingly low rate regardless of whether a given power is produced at 500, 1000, or 2000 rpm. Broadly speaking, this type of wear is controlled by design and specifications, the engineer's principal tools. But, albeit he does not relinquish control, he loses the principal part of it when the engine leaves his hands; and to this mainly are due the often perplexing shortcomings of an engine in view of its factory record. Also, the higher the rpm at which the apparent shortcoming, the more pronounced will be the outcry.

When, as frequently happens, post mortem activities uncover violation of the first principles of care and maintenance, so strong is the prejudice that its owner, while reluctantly admitting that things might be as represented, will resume business inwardly convinced that had he thus victimized a slower engine, his troubles would have been nil. Now, if efforts to the contrary have failed to change his mind, and he adopts a slower engine, aforesaid efforts nevertheless will have succeeded in pointing a moral, with the result that the lesson is applied to the slower engine, and once more do we hear declarations to the effect that high speed is destructive.

Nor is the above mental process reversible. If a 900-rpm engine gives trouble, and you have an 1800-rpm engine to sell, the latter is confidently expected to give twice the trouble, at least. High speed may be called destructive once we know exactly what is meant by high speed, that is to say, when an agreement is reached as to some border line which will separate conceivably tolerable conditions from intolerable ones. It would be superfluous to go into lengthy discussions of some of the major advantages of relatively higher engine speeds. The automobile is a good example. In the agricultural field the trend toward a greater utility range of tractors, as exemplified by the increasing use of the pneumatic tire, will make its own special demands to be met with higher engine speeds. If we are to accommodate ourselves to the trend, a more accurate interpretation of the meaning of engine speed appears indispensable. Although originality is not claimed by the writer, much of what is said having been stated before in some form or other, he feels that the suggested combination of design factors will bring to an old term a newer and truer significance.

Since, to be mutually helpful, comparisons must be predicated on a commonly accepted method, formulas for the determination of high speed are given. It is not claimed that all factors will agree with laboratory results, nor that the quantities arrived at will check with precision—any more than our time-honored horsepower formula checks with the horse, much depending on the kind of a horse he is and the method of harnessing him to the load—but on broad principles they will be found to agree closely with general practice. Seeing that, if speed is the predominating thought, reciprocating parts are made as light, and compression ratios as high as practicable, computations should assume aluminum pistons and a compression ratio as some maximum function of the displacement of one cylinder; notwithstanding that the engine in question might be furnished with iron pistons and low compression. But that seems far enough to go in the matter of substitution if more or less standard practice is adhered to.

$$\text{High Speed (rpm)} = \sqrt{\frac{P \times 70400}{W \times S \times F}}$$

where $W$ = reciprocating weight $(B^3 \div K) + (B^{2.5}L \div 2M)$
$B$ = bore
$S$ = stroke
$D$ = displacement of one cylinder, cu in
$L$ = length of connecting rod
$P$ = total combustion pressure = $3.14\, C\, (B \div 2)^2$
$C$ = combustion pressure, lb per sq in
$R$ = compression ratio
$F$ = inertia factor, depending on $2L \div S$
$K$ = weight factor (aluminum piston assembly)
$M$ = weight factor (forged steel connecting rod assembly).

Unless otherwise stated, the foregoing values are in pounds and inches. Should logarithmic tables not be available, the term $B^{2.5}$ transformed into the square root of the fifth power will give the same result by simple arithmetic or slide rule.

The following tabulations give values of items $C$, $R$, $F$, $K$ and $M$:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| When $D$ is | 1.0 | 30 | 60 | 100 | 150 | 210 | 280 |
| $R$ is | 7 | 6 | 5.4 | 5 | 4.63 | 4.38 | 4.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| When $B$ is | 2 | 3 | 4 | 5 | 6 | 7 |
| $K$ is | 10.5 | 5 | 18 | 19 | 20 | 20 |
| $M$ is | 60 | 70 | 75 | 80 | 85 | 90 |

THE UTILITY RANGE OF AN INTERNAL-COMBUSTION ENGINE DESIGNED FOR OPERATING AT HIGH SPEEDS IS MUCH GREATER THAN THAT OF AN ENGINE PRIMARILY INTENDED TO OPERATE AT A MORE OR LESS FIXED SPEED VALUE OF THE LOWER ORDER, IS THE CONTENTION OF THE AUTHOR OF THE ACCOMPANYING PAPER, AND HE CONTENDS FURTHER THAT, IF PROPERLY APPLIED, HIGH ENGINE SPEEDS MAKE POSSIBLE FAR-REACHING ECONOMIES

| | | | | | | |
|---|---|---|---|---|---|---|
| When $2L - S$ is | | 4.5 | 4.25 | 4.0 | 3.75 | 3.5 |
| $F$ is | | 1.22 | 1.23 | 1.25 | 1.27 | 1.28 |
| When $R$ is | 3 | 4 | 5 | 6 | 7 | |
| $C$ is | 135 | 227 | 322 | 378 | 510 | |

By plotting above values and drawing a smooth curve, intermediate points can be determined.

Accordingly, the 5-by-6-in engine approaches high speed in proportion as the peak power rpm reaches 2540 rpm. Likewise the 4¼-by-4½-in engine with 3540 rpm. The former's operating speed of 900 rpm may be expressed as 35 per cent of high speed, the latter's as 51 per cent. Output being equal, the small engine runs 45 per cent faster than its large competitor; not 100 per cent.

Further modification in favor of the higher speed engine is in order if thought is given to the fact that the duration of a destructive force plays an important part in the problem of lubrication. While at the operating speeds considered the frequency of application was doubled in the small engine, the duration of peak loads was reduced 50 per cent. This, coupled with the circumstance that small surfaces are more speedily wetted by the lubricant than larger ones, should be taken into account when judgment is passed on a so-called high-speed engine.

## Discussion by O. E. Eggen[1]

MR. EVELYN, in his paper, deals with the subject of high-speed vs. low-speed engines principally from the viewpoint of speed classification. I agree with Mr. Evelyn in that the nature of the load is, or should be, the governing factor, and that the subject of high-speed vs. low-speed engines must be considered as relative.

The tendency in tractor design, for ten or more years, has been to increase the engine speeds and at the same time, naturally, to decrease the cylinder bore, giving the prospective customer the maximum power per cubic inch displacement, and per dollar of engine cost. Speed of rotation, when applied to a tractor engine, must be based upon the problems present in the engine, as well as those present in the unit to which it is attached, and the limitations of such a mechanism.

Generally speaking, transmission design with larger gear reductions, resulting from higher engine speeds, should not present a problem that can not be overcome by the tractor designer. Operating costs have been continually lowered, but the principal demand of the consumer, especially during these trying days of depressed prices, is for a still further decrease in the operating cost of his machinery. In a tractor this can hardly be accomplished by an increase in the operating speed, due to farming limitations.

An increase in economy will have to come from a decrease in first cost, and a decrease in operating expense. If the specific output of the tractor engine can be increased, a smaller and lighter engine will do the same work. There is no question but what the smaller engine could be manufactured more economically, even though it would have to be built somewhat more carefully with respect to balance, cylinder and piston seal, etc., due to an increase in compression and the higher speeds necessary.

A decrease in the operating expense will have to be obtained from an increase in the compression ratio, which should be possible due to the decrease in cylinder bore; and by the use of improved and more volatile fuels. An increase in compression would materially increase the amount of work done with a given amount of fuel. If the speed of rotation is increased along with the change in compression ratio, the specific output of the motor would be increased considerably. Cubic inch displacement per horsepower developed will have been materially reduced, effecting the desired economy.

It is questionable whether many of the problems connected with the present tractor engines, operating at an average speed of approximately 1250 rpm, would be aggravated by an increase of speed. There have been marked improvement in materials, construction, balance, lubrication, and fuels, that cannot and should not be overlooked, and of which advantage should be taken. Generally speaking, crank pin bearing loads, due to explosion pressures, are greater than the pressures due to the inertia forces of the reciprocating parts. Quite frequently in such cases it would be desirable to step up the speed of the engine to a point where these loads will balance so as to actually decrease the resultant loads, and to get smoother engine operation.

Rapid wear of the cylinder at the piston top ring can be attributed to slow-moving pistons as well as the presence of dirt. High explosion pressure suddenly applied reaches the back of the top ring, resulting in high ring pressure, destruction of the oil film, and, in time, a bell-shaped cylinder. With fast-moving pistons, or higher relative speeds, the explosion pressure does not reach the piston rings so readily.

Inefficient air cleaners have been the cause of many troubles, and no doubt have been a factor in retarding the development of farm tractor engines. Progress has been made in the perfection of the air cleaner, making it possible to purchase cleaners that are high in efficiency at practically all loads, and within reasonable speed limitations.

Full pressure lubrication to all bearings that are subjected to high pressures and temperatures, plus a thorough filtering of the oil before it is used, has enlarged the permissible speed range. Improved chemical stability of the present-day lubricating oils, the reduction of sludge and other products of oxidation, plus an improved viscosity index providing the proper viscosities for different operating temperatures, have contributed greatly toward better engine performance.

There is no reason to believe that a tractor engine working perhaps 65 to 100 full days a year could not be designed to have a satisfactory life if advances in design, which have been made in internal-combustion engines in connection with their application to passenger cars and trucks, are made to apply to tractor engines.

[1]Chief engineer, Oliver Farm Equipment Co. Mem. A.S.A.E.

## Pressures and Loads of Ear Corn in Cribs

*(Continued from page 125)*

and the loads on the cross-bracing of corn cribs are much larger than is commonly supposed.

Failures may be due to lack of cross-bracing to resist outward pressure, or to improperly designed cross-bracing that is broken by the weight of corn above.

It is believed that the data presented in Figs. 2, 4, and 5 provide a basis for safe design of cribs 8 ft in width, and that with proper allowance for increase in loads due to greater width of crib, these data may be used for designing cribs up to 12 ft wide. The factor of safety should be large enough to provide for variations in weight of corn and unusually rapid filling of the crib.

# Economics of Modern Design of Internal Combustion Engines[1]

By E. S. Chapman[2]

THE TITLE of this paper seems to me well chosen, as we (executives) have to deal with the economics of our business problems, leaving the technicalities in the more capable hands of our engineers. To us, "modern design" implies "improved design," and for the consideration of this group, the improvement may be judged from two standpoints, namely, that of the ultimate user, and that of the equipment manufacturer who is considering a power plant for his product.

These two considerations are parallel to a certain extent. Both manufacturer and user are interested in the first cost of the engine, the overall efficiency and economy of operation, the utmost availability when power is needed, and adaptability to rapid and economical servicing as occasion requires. The manufacturer has additional considerations of perhaps equal importance. In addition to low cost of the engine or power plant, the investment required to make it available has an important bearing, as well as the necessity to obtain a sufficient supply of engines promptly and in varying quantities to meet the seasonal and other fluctuations which affect production, and without having to tie up excessive capital in production facilities or inventory.

Many of these necessary attributes of the desirable farm equipment engine point plainly toward automotive designs and automotive engine producers as the logical sources for power. Comparisons of present-day automotive engines with the so-called purely industrial or agricultural engines tend to favor quite strongly the automotive type. Agricultural and construction equipment have requirements very similar to the commercial automotive field, in that both are sold on a basis of earning power, both are subject to fairly constant loads approaching full capacity, and both may have severe conditions of dirt, heat, and operation and maintenance by hired help rather than by their owners. Commercial automotive equipment has the further severe requirements of high total operating hours per year and relatively high operating speed, and the trend toward speed is decidedly noticeable, and will become more pronounced, in agricultural service, especially for tractors.

It is comparatively high operating speeds which has forced the automotive engineer toward engines of great structural strength in proportion to their displacement. Hence, we are likely to find larger bearing areas and more bearings, better distribution of oil under pressure, reduced inertia forces through refinement in material and design of reciprocating parts, scientifically designed counterweights, more effective crankcase ventilation, and similar features of design which make possible a high specific output per pound and per cubic inch of displacement, as compared with the average commercial engine. For example, a recent study shows an average output for current automobile engines of from 2.86 cu in per horsepower to perhaps 5 cu in per horsepower, depending on the speed of operation, as compared with from 6 to 16 cu in per horsepower at governed speeds for representative commercial engines.

Tractor service promises to encroach somewhat on the truck field, and the requirements will doubtless become more alike with the increasing popularity of pneumatic tractor tires and higher road speeds. This should and will bring the tractor into road hauling service, increasing its field of utility and its useful hours and days of operation throughout the year.

Assuming, if you will, that suitable automotive designs of engines are available from automotive production, the economic advantages follow so surely and so distinctly that we feel confident of a much closer kinship between agricultural engineering and automotive engineering in the near future. The successful automobile or truck engine plant of today has perhaps half a million dollars or more invested in cylinder block machining equipment and a comparable amount involved in crankshaft production. In fact, all of the major component parts of the engine must be produced by and with facilities which would be economically out of the picture, if production were lined up on the basis of perhaps twenty-five or fifty a day, as compared with from twenty-five to one hundred and twenty-five per hour, or 450 to 2250 per day of two nine-hour shifts. It has been our experience that quality of work and true interchangeability follow high production scientifically equipped. For example, in foundry practice the elaborate metal pattern equipment, modern methods of core making and scientific control of the materials and melt provide a quality of casting impossible with facilities based on smaller volume.

In high production machine and assembly practice, with the testing and inspection systems which accompany it, dimensions must be accurate or assembly is hampered.

The large sums expended for research and development by progressive automotive manufacturers assure up-to-date designs and continued progress. These great sums invested in research and production facilities are a true economy when amortized over the relatively great number of units of one design. Progressive engineering may raise a question in some of your minds as to too frequent model changes, with all that that implies in service complications, redesigning of your equipment, etc. This, of course, is important, but not as important as appears at first. If you will check any current production engine over a period of years, you will find the major changes occur at comparatively long intervals. The year to year improvements are more refinements and are almost always brought out with the idea of interchangeability prominent in the picture.

Changes in design are too often regarded with apprehension and antagonism. Of course, they make work for some people and cause us to exercise our minds, but it is too easy to lose sight of the fact that an industry, like an individual or a nation, can die of inertia if we do not have the repeated stimuli of new ideas, methods, and designs. The large production engine builder is confronted with a service problem of a magnitude in proportion to the number of units sold. This fact automatically restrains him from too radical and frequent changes where they are not necessary, and accounts for the surprising continuity of design which is apparent to the real investigator.

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers held at Chicago, December 1933.

[2]President, Amplex Manufacturing Co., division of Chrysler Corporation.

The story of some of our experiences with modern engines may interest you, and I wish first to refer to a type of service far removed from farm and tillage problems. I refer to marine engines which have undergone a truly remarkable evolution in the past several years. There was probably no more conservative or tradition-bound group of individuals than were the boat builders and many boat owners up to the beginning of the last decade. The boat building art is older than history. It is primarily a handicraft trade and abounds with individual opinions and prejudices. When the internal-combustion engine became a factor as a means for boat propulsion, the early engines were unreliable, inefficient, and cumbersome, just as the early types of any mechanism are likely to be. They had to compete with steam plants which, of course, are inherently heavy, large, and required a lot of space in the boat, so that even the earliest gasoline boat engines were marvels of compactness in comparison.

The marine engine developed very slowly largely for this reason. Credit must be given the more progressive boat builders for recognizing the possibilities of more modern types which became available to the marine trade perhaps six or eight years ago. Since that time development has been rapid and the influence of modern internal-combustion engines on hull design, the decreasing price of boats, and the increasing popularity of boating has been very marked. Today we find marine engines of perhaps 220 cu in of piston displacement, for example, developing 85 hp, driving boats 35 miles an hour and operating for hours on end in the hands of every type of individual, at speeds from 3000 to 3600 rpm. In cruising waters it is taken as a matter of course for a private boat owner to start out for a run from New York to Halifax, Bermuda, or the Florida ports without fear of engine failure, in spite of the very real hazards which would be present with less dependable power plants.

This brings us to the much discussed problem of engine speeds. Too often a judgment is passed on the basis of speed of rotation, without an analysis of the piston speed and inertia forces involved in the particular engine under consideration. Analysis of a modern four-cylinder engine and two six-cylinder engines disclosed the following:

| Engine | No. cyl. bore and stroke, and cyl. displacement | rpm | bhp | Piston speeds, fpm | Recip. weight, lb | Recip. weight, per sq in of cyl. area | Total inertia force at rpm, lb | Crank pin dia., length and net area | Inertia per sq in of net area, lb |
|---|---|---|---|---|---|---|---|---|---|
| | 4 cyl. | 1200 | 28 | 950 | | | 266 | 2 in | 119 |
| PA | 3⅝x5 | 1800 | 42 | 1425 | 2.15 | 0.2084 | 600 | 1⅜ in | 269 |
| | 196 cu in | 2700 | 56 | 2137 | | | 1350 | 1.15 sq in | 606 |
| | 6 cyl. | 1200 | 28 | 825 | | | 218 | 1 15/16 in | 116 |
| PC | 3⅛x4⅛ | 1800 | 41 | 1237 | 2.06 | 0.2685 | 491 | 1 in | 261 |
| | 190 cu in | 2700 | 60 | 1856 | | | 1105 | 0.969 sq in | 588 |
| | 6 cyl. | 1200 | 42 | 1000 | | | 397 | 2 3/16 in | 147 |
| Z | 3⅝x5 | 1800 | 61 | 1500 | 3.14 | 0.3041 | 894 | 1¼ in | 331 |
| | 309 cu in | 2700 | 100 | 2250 | | | 2015 | 2.70 sq in | 747 |

From this you will see that at the rotative speeds that best lend themselves to present agricultural machine design, these engines are operating at piston speeds and bearing loads a fraction of the value of these factors at the rotative speeds under which the same engines are giving continuous and satisfactory performance over long periods of use.

It is a tendency of all of us to regard our particular field and product as highly specialized. This tendency may lead us into such a specialized position that we end up in the blind alley of prohibitive costs and fixed, inflexible sources for our power. An example of this rather broad statement is the demand for hand holes in the side of crankcases. This persisted in the marine engine business to the point of absurdity and some people penalized their designs from the standpoint of cost and possible oil leaks to the extent of putting such hand holes and covers on engines of a design which prohibited a grown man putting his hand into the crankcase, to say nothing of making any adjustments or performing any other useful operation through these tiny apertures.

Another example can be found in the erstwhile requirement for separate cylinder bore liners. This is much more justifiable than the crankcase inspection holes, but is still a good example of how theoretically attractive ideas can penalize a product. This statement is made in the light of considerable investigation of the subject in connection with truck, bus, and marine service. The separate cylinder wall, of course, involves two joints in each cylinder which must be sealed under temperatures from well below zero to over 200 deg F. The additional cost is quite a factor and the savings from a service standpoint far more apparent than real. It is usually true that in the case of a large production engine a new or rebored cylinder block with properly fitted pistons and pins can be obtained by the user on an exchange basis for a smaller outlay than the installation of new cylinder liners. Where liners are installed as a service operation, unseasoned castings are matched with well-seasoned ones with the corresponding difficulties in obtaining tight joints. New pistons and pins should be supplied in either case. It is easy for us and probably for many of our friends in this industry, to be attracted to an idea or feature which adds an alluring paragraph to the sales talk for our product, but we are sometimes too prone to stop short of the complete analysis required to find out whether in the long run the feature is economically sound for us and for our customers.

Another interesting attitude frequently encountered is the resistancee to the adoption of six-cylinder designs. As we all know, the conventional six-cylinder engine provides the fewest number of cylinders which will give inherently balanced rotative and inertia forces. Under modern design and production methods, six-cylinder power plants are available at costs comparable with power plants of fewer cylinders and similar power. The lighter reciprocating weights which follow with additional cylinders are a real advantage. The absence of vibration does more for the operator of the machine than we like to admit. Vibration is disturbing to the nerves and destructive to the mechanism, and implies wasted energy that is hard to justify. We confidently predict that the more courageous and successful designers of the near future will take advantage of the inherent merit of six-cylinder engines to their profit.

In closing, I wish to state that I realize these remarks are strongly tinged by our association with the automotive industry. I also realize that we are presenting but one of many sides of a case which can be discussed at great length, and probably almost as many opinions can be supported as

there are people involved in the discussion. I do feel, however, that the automotive industry has contributed and can and will contribute a great deal to agricultural engineering, and is too rich in possibilities for cooperation to be disregarded as engineering programs are laid out to take advantage of the improved farm market which is just ahead of us.

## Discussion by A. W. Lavers[1]

THE TRACTOR ENGINE of today is subjected to more severe treatment in many respects than the engine of several years ago. It is required to operate for longer periods of time under very severe conditions and in temperatures ranging well over 100 deg to below freezing. It is working at from 75 per cent to full load a great deal of the time. Also it is required to work in very dusty conditions where the dirt and sand are thrown up by implements and the wheels of the tractor, and a cloud of dust is formed around the tractor which makes it impossible to see the machine or operator at times. The engine is also often put into the hands of inexperienced men who know little about the care of machinery of this sort. Also when used in the field, the work that it is required to do has to be performed very quickly due to seasonal conditions, and the operator does not want to take very much time to grease, oil, or make adjustments. For these reasons the tractor engine has to be built so that there is very little adjustment required by the operator.

In order to build a machine that is as foolproof as possible and where adjustments are more or less taken care of automatically, it is necessary to put on attachments, to prevent excessive wear of the various parts of the engine from dirt, which do not require frequent attention. These are air cleaners, oil filters, and proper seals for all the various shafts and moving parts. An oil filter is a very necessary attachment for tractor engines. We have inspected engines on which the air cleaner was not taken care of, or which did not clean properly, and found that the main, connecting rod, and camshaft bearings were in very good shape, which was entirely due to the oil filter functioning properly and removing the dirt from the oil before this oil was pumped to the bearings. On this same engine the cylinder, piston, and ring mechanism was very badly worn from the dirt that entered through the air cleaner.

On the other hand, if the air cleaner is functioning properly and properly taken care of, it will keep out a great percentage of the dirt which would enter through the carburetor on a tractor engine. This protects the intake valves, valve guides, cylinders, and pistons. An air cleaner that will properly take out over 95 per cent of the dirt from the air and will not require too much attention is very necessary on a tractor; in fact, it is nearly as necessary as an oil pump.

As regards the material used in an engine, such as cylinders, it has always been a question as to whether cylinders made of a hard material would be economical and practical or not. We believe that whatever excessive wear does occur in a cylinder is due principally to dirt. In a test made at the University of Minnesota this year, cylinder sleeves of various materials were tested for wear when an abrasive sand was allowed to enter the engine. In these tests cylinders were made of ordinary cast iron, nickel chromium cast iron, and one set was made of nitralloy steel. The results of these tests indicate that when sand is entering an engine there is very little difference in the wear of the cylinders whether they are hard or soft; in fact, there was so little difference that it would not pay for the extra cost of better material. These tests prove that the dirt must be kept out of an engine in order to get long life.

It is necessary to keep down the oil consumption of an engine as well as to obtain good economy and power. To do this, the cylinders and rings must be kept in good shape and this cannot be done if there is rapid wear of these parts.

In conclusion, I would say that a tractor engine must be well built, good material must be used, and proper provision must be made to keep the engine parts clean and well lubricated. The bearings must be of good capacity. The tractor engine must be built to stand abuse and very hard work. At the present time a tractor engine must be equipped to burn distillate.

[1]Chief engineer, tractor division, Minneapolis-Moline Power Implement Company. Mem. A.S.A.E.

## Discussion by C. E. Frudden[1]

THE PRESENT interest in farm tractors of smaller size provides an opportunity to incorporate features in engine designs which will make these newer tractors not simply boiled-down editions of previous larger models, but machines of very much greater usefulness. Generally speaking, tractors used on farms growing diversified crops have been purchased to do the hard jobs, or the heavy work. Plowing has been the first and most important job, and horses have been retained to do most of the lighter work, which, in terms of man-hours, generally exceeds by many times the job of plowing. Perhaps the tractors we have been building, even those of the general-purpose type, have been none too well suited for doing the lighter work, and certainly they have been too expensive to operate under these conditions as compared with horses. Possibly we would have a better and more useful tractor, if we were to design it primarily to do as economically as possible such jobs as harrowing, planting, cultivating, mowing, harvesting, wagon hauling, etc., and then get the plowing out of the way in ten or twelve days, instead of in six or eight.

This is a big country, without considering the rest of the world, and to discuss a few general requirements in terms of suitability for the cotton grower, the wheat grower, the corn farmer, and the hundreds of combinations of crops raised in all sections, may not lead to any final answer, but should bring out certain general considerations for a proper starting point at least.

Suppose, rather than to talk in very general terms, an engine suitable for a small general-purpose type of tractor be considered; and let us limit the proposition still further to one that may be classed as a two-plow size. Certainly a tractor in this classification must do well and economically a great variety of work, and it may therefore be too light to pull two plows in August, even though the engine is powerful enough to spin the wheels; but it should pull a grain or corn binder all day long on ten gallons of gasoline, otherwise the farmer can not afford to use it at all for this work. Before getting to the engine specifications, we will have to assume that the tractor is designed with a transmission providing a wide selection of gear ratios, certainly not less than four, and in order to do economically many of its jobs, air tires are available.

How powerful should the engine be and how big the cylinders? Well, my guess is that the engine should be able to develop about 25 hp, as tested at Lincoln. That is, at some speed at which this power may be maintained continuously with reasonable exhaust temperatures, reasonable bearing loads, oil temperatures, etc., it might be rated 25 maximum horsepower. Accordingly, to our present ideas, such an engine will require about 200 cu in displacement,

[1]Chief engineer, tractor division, Allis-Chalmers Manufacturing Company.

FROM THE STANDPOINT OF SUITABLE FUELS, AN ENGINE NECESSARY FOR A SMALL GENERAL-PURPOSE TRACTOR OF THE TWO-PLOW SIZE, ACCORDING TO MR. FRUDDEN, SHOULD BE AS FLEXIBLE AS ANY TRUCK ENGINE

if run at 1200 to 1400 rpm, these figures being in accordance with present-day tractor engine ideas as to power and speed. Breathing clean air, burning good fuel, and lubricated with good oil, an engine will run a long time under these maximum conditions.

This maximum is all right for plowing, for threshing, etc., but when pulling a mower or grain binder requiring only, say, 10 to 15 hp, the engine speed should be reduced to, say, 600 or 800 rpm, where it will operate much more economically than at 1200 rpm; and a transmission gear should be provided which will produce the proper speed of travel for the drawn implement at the reduced engine speed. Likewise, when cultivating corn at slow speed, there is no sense in racing the engine and operating in a low gear at a cost of two gallons of gasoline per hour, when at reduced engine speed the fuel cost may be only 1 to 1½ gal per hour. And, again, using the cultivation of corn as an example, later in the season it is entirely feasible to travel at 6 to 8 mph (miles per hour), perhaps even faster; and even under these conditions 25 hp is not needed. For economy the engine could well be run at 800 to 1000 rpm, transmitting through a properly selected gear ratio to provide the desired speed of travel. Belt work on the farm provides more examples. Threshing and silo filling will probably require all the power the engine is capable of delivering at the maximum safe speed selected for heavy loads, but there is a lot of wood sawing, corn shelling, feed grinding, etc., requiring 10 hp, or less, and at reduced speed the 200 cu in engine will deliver the reduced horsepower with exactly the same economy as any smaller engine.

The point in the above is that there is just as much light load work required of the tractor as there is heavy work, at or near its capacity; and the engine, to do these jobs economically, must be equipped with a good governor capable of maintaining uniform engine speed over a very wide range of engine speed operation. At the same time, details such as manifolding, carburetion, fan and radiator design, etc., need to be given due attention.

At the other end of the engine speed question is that of maximum speed. Certainly any engine meeting the specifications as outlined above should not be limited to 1200 or 1400 rpm for occasional running. On the roads hauling suitable trailers, or traveling light between house and field, or from farm to farm, such engine speeds as are practical for motor truck service should also be available for the tractor, and who would say that 2000 rpm is a high speed for a 200 cu in engine under these conditions? We may need a two-speed drive for the governor for obtaining the slow-governed speeds required and a governor cut out for high road speeds; but in any case the governor becomes as it should be—a device for maintaining uniform engine speed so as to produce good work, and not a speed-limiting device.

Designing the engine for performance as suggested above, and combining it in a tractor with a properly selected gearset of sufficient ratios, and air tires for further increasing the tractor's versatility, will most certainly result in greater economy of operation, greater usefulness, and more hours of operation, all to the end of making our tractors better investments.

On the subject of suitable fuels for such an engine as has been suggested, and without attempting to go deeply into this subject which is scheduled for later discussion, it is evident that as outlined above the engine should be as flexible as any truck engine. No good reason exists for burning a cheap, low-grade fuel in a tractor engine that does not apply with equal force to the use of it in passenger cars and trucks. An engine of such a size as we have been discussing when used in a tractor may burn 800 to 1000 gal of gasoline per year. The same size of engine used in a passenger car, covering 8000 miles per year and averaging 12 mpg (miles per gallon), will use 660 gal of gasoline. The passenger car or truck engine will perform just as well when fed kerosene or tractor fuel, as will the tractor engine; but we demand performance from our cars, and even the farmer buys good gasoline for this purpose. Perhaps it is the tax situation which makes it necessary for us to lower the compression of our tractor engines and to unnecessarily heat the intake manifolds, both tending to reduce power output and increase fuel consumption, besides ruining almost completely the flexibility of the engine for widespread use.

The Louisiana farmer who chooses to burn six or seven-cent tractor fuel, rather than to pay 8½ cents tax for the privilege of burning a good ten-cent fuel, may think he is saving money, and perhaps he is. But one thing is sure, when he does this, the government collects no tax and the farmer's cost of producing his grain is increased just the same. This is more than an engineering problem; if he doesn't pay his tax on the gasoline, he has to pay his tax in some other way to balance the state's budget anyway, and he is further out of pocket because he burns the cheap, unsuitable fuel in one of the most expensive pieces of machinery he owns.

Our tractors remain in service many more years than cars and trucks do; so the question of overhaul and repair is very important. Accordingly, removable cylinder liners, replaceable bearing shells (which are strictly interchangeable in the field), hardened exhaust valve seats, and similar features, are very desirable. We want to build them so they are more versatile, so they will work more hours per year, so that less power of other type needs to be kept on the farm, so they will cost less to buy and less to run, and will live to a ripe old age.

# Fuels for Spark-Ignition and Compression-Ignition Engines[1]

By J. B. Fisher[2]

IT HAS BEEN obvious to all who have, if only casually, followed the developments in internal-combustion engines the past three years that power plants for industrial and agricultural uses were about to be changed to meet the demands for more economical fuels—a demand that the depression and excessive taxation have emphasized as a crucial point of attack in effecting sharp reduction in operating economies of engines, whether in tractors, railcars, trucks, or other industrial uses.

Manufacturers using engines have been keenly aware of the sales demand for engines operating on cheap fuels, and in the tractor field it has been met almost entirely by compromising what might have been perfectly good gasoline engines, until they are not very efficient engines on either gasoline or kerosene and distillate fuels. While good fuel economy records have been made by some of these engines, they have often been made at the expense of brake mean effective pressure, or with higher maintenance costs than gasoline engines. In many cases the field performance on distillate or kerosene was such that the owner preferred to pay the additional cost for gasoline rather than to continue with low-grade fuels.

The engineers and petroleum technologists, although they have striven most diligently to produce engines and fuels to meet these demands, until recently have been handicapped by lack of suitable equipment for investigating some of the unknown qualities of the fuels with which they were working. And after producing an engine, after months of careful testing and research, to operate on kerosene or the lighter distillates with a fairly decent and quiet performance, even at full load, it was most disconcerting when these same engineers hustled down to San Antonio or Phoenix for the winter field try-outs to hear these self-same engines trying to give an imitation of a boiler factory with more or less disastrous results to the valves, rods, main bearings, and the engineer's peace of mind.

A quick check-up often showed that the fuel was of the same gravity, flash, and distillation characteristics as the fuel used in the laboratory. Something had happened! But it had happened approximately ten or fifteen million years ago when nature was brewing the fuels that today make the internal-combustion engine possible. This very important factor that was built into the fuels at that time was its molecular stability—its behavior under given conditions of temperature and pressure. This quality is not indicated by any of the specifications usually associated with engine fuels, but it is by far the most important single quality that the fuel possesses when viewed from the standpoint of the petroleum technologist or engine designer.

If the designer is designing a carbureted engine, he must use all his knowledge to prevent unstable fuels from detonating—from breaking down and the whole charge exploding instantly instead of burning in an orderly manner as the flame front advances through the mixture. He must pay scrupulous attention to the cooling of exhaust valves, spark plug points, piston heads, and any other points that might encourage detonation. If, on the other hand, he is designing a compression-ignition engine, he may profitably incorporate in the combustion chamber some hot spot near where the fuel enters to deliberately encourage the first fuel that enters the chamber to burn quickly. If this is not done and exceptionally stable fuels are encountered in service, the result, particularly when starting with cold engines, is apt to be a high percentage of the fuel charge in the chamber before combustion starts with excessive pressures and a possible failure of the engine. The rate of pressure rise under such conditions is extremely abrupt, and the impacts and stresses produced by the abnormal rate of

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December 1933.

[2]Chief engineer, Waukesha Motor Company. Mem. A.S.A.E.

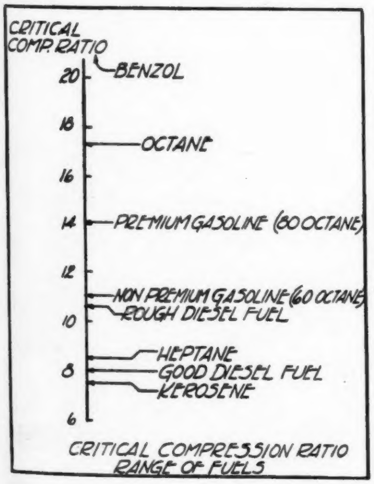



FIG. 1

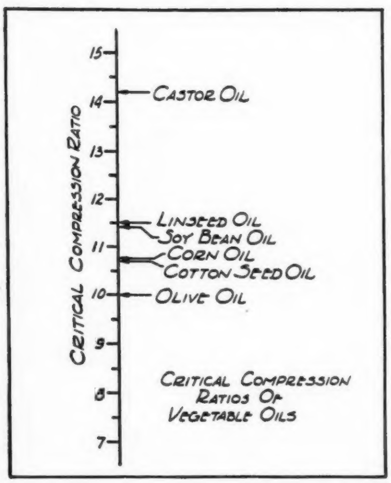



FIG. 2

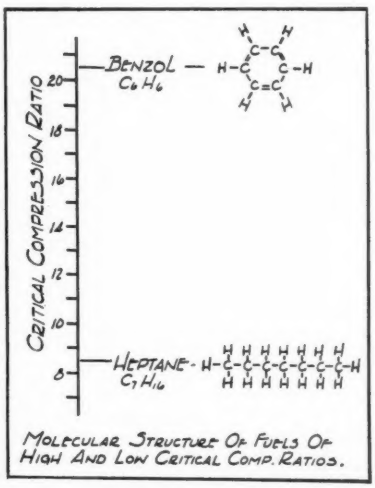



FIG. 3

pressure rise are far in excess of the designer's original calculations.

In designing carbureted engines, the designer was inclined to play safe and use a relatively low compression ratio—too low for good thermal efficiency. Given freedom from danger of detonation, he would like to use a compression ratio as high as 7.5 to 1 to get high thermal efficiency, but, except with highly doped fuels, this ratio would be impossible. To burn kerosene or distillate safely, he lowers the ratio to possibly 3.5 to 1 or 4 to 1, and he forever surrenders the chance to secure high brake mean effective pressures and, with them, good fuel economy, for high brake mean effective pressures necessitate the use of high compression ratios. The high ratios are also desirable to give better fuel economy. The wasteful effects of low compression ratios are immediately apparent when running a series of tests with variable compression ratios. It was to enable the designers of carbureted engines for agricultural and industrial purposes to use higher compression ratios that led to our recommendation of establishing three or four standard fuel specifications for kerosene or distillate that would let the designer build his engine with definite fuels in mind.

The one quality which the engine owner wants to know about the fuel he buys is, therefore, its thermal stability. This quality is easily determined by finding out what compression ratio is required to cause it to ignite in a Diesel engine—its critical ignition ratio. These ratios are shown in Fig. 1 for quite a variety of fuels.

Note how kerosene ignites at a very low ratio—only 7.5 to 1 being required to cause it to ignite in the fuel research Diesel. It is easy to visualize how, in a carbureted engine burning kerosene, the increasing pressure and temperature in some part of the chamber, shortly after ignition takes place, rises to the pressure and temperature we have in this Diesel engine with a 7.5 to 1 ratio. When this critical temperature is reached in a kerosene engine, the unburned portion of the mixture burns almost instantly with the same characteristic knock we hear in many Diesels, where too much fuel gets into the chamber before ignition gets under way.

### Wide Variations in the Critical Ignition Ratios of Available Engine Fuels

In other words, with only a 7.5 to 1 ratio required to ignite kerosene with only the heat of compression, we can see how close the tractor engineers have been to making a Diesel engine out of their kerosene engines without knowing it. In fact, most of us have heard kerosene engines that outperformed Diesel engines, if noise is any criterion.

Note also the wide variations in the critical ignition ratios of other fuels (Figs. 2 and 3). Many fuels are available which are quite cheap, but their critical ignition ratios render them impossible for consideration as Diesel fuels. Fuels with high critical ignition ratios are too stable to be ignited by the compression temperatures of conventional Diesel engines, particularly when operating in cold weather or at high altitudes. The very large Diesel engines of 10 or 15-in bores are not so susceptible to minor changes in fuel characteristics as small ones, as they have less wall area per cubic inch of combustion chamber volume to absorb heat and chill the compressed air. A 5-in bore Diesel will have roughly, two times the combustion wall area per cubic inch of volume as a 10-in bore, which means relatively far more area to absorb the heat built up on the compression stroke. This means that at the end of the compression stroke the actual temperature of the air in a 5-in Diesel with a 12 to 1 compression ratio would be far lower than the temperature of the air in a 10-in Diesel with the same ratio. It is the failure of some designers to appreciate the importance of this fundamental point that causes complaints to arise on hard starting and unsatisfactory operation, particularly with adverse weather conditions and high-ignition ratio fuels.

In Germany there are produced, as a by-product in making gas, 500,000 tons of gas oil a year, which looks like a wonderful Diesel fuel until one tries it. It simply will not ignite in a compression-ignition Diesel. The answer is simple. It required, when tested in the fuel research Diesel, a compression ratio of 22 to 1 to ignite it. Benzol, alcohol, and many other vegetable oils are also impossible as Diesel fuels for the same reason. It has been said that out of all the petroleum taken from the earth only fifteen per cent of it is of the right stability for use in a Diesel, and a high percentage of this is ruled out due to the impractical compression ratio required to ignite it.

We thus have a brief but comprehensive picture of the fuel situation that confronts the engineer who must design or choose a power plant for a tractor engine. He can choose a gasoline engine with a good compression ratio and secure excellent power and fair economy and swallow the high cost of fuel. He can choose to lower the compression ratio; heat the mixture in the manifold, thus lowering his volumetric efficiency still further, and burn kerosene or distillate with fair economy but with a relatively low brake mean effective pressure. Or he can choose a compression-ignition engine with a higher initial cost and with it face the question of always getting just the right fuel and starting problems, particularly in cool weather with valves not in the pink of condition as when the tractor is first put in service. Valves and piston rings simply must not leak in a Diesel if starting is to be assured.

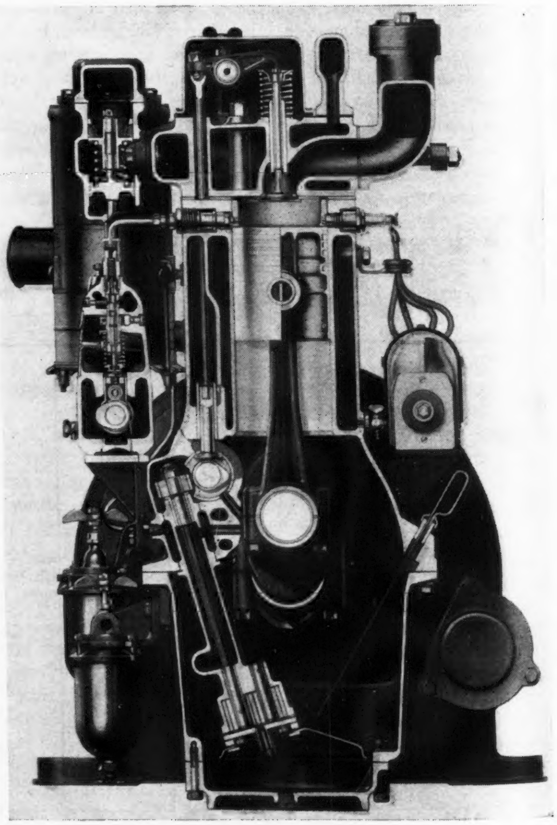


FIG. 4

A fourth alternative is now being offered him which bids fair to solve most of the problems that we have set forth. This is using a solid injection engine, but, instead of depending on the heat of compression, using a spark plug and igniting the fuel in the conventional manner.

In this type of engine, the fuel is injected in a manner similar to a Diesel engine, using conventional fuel pumps with a fuel injection pressure of 1500 lbs per sq in. A spark plug is located opposite the injection nozzle. To secure a thorough mixture of air and fuel, air is introduced on the suction stroke at high speed and tangentially with the bore, causing it to rotate rapidly. This rotation continues throughout the compression stroke, and as the air sweeps by the injection nozzle it carries the fuel around the chamber and produces a thorough mixing of air and fuel. These air speeds have not only been calculated, but they have been measured and suitable formulas set up to govern the design of this type of engine up to large bores.

As we no longer are concerned about critical ignition ratios or loss of heat to the cylinder walls on the compression stroke, because of using spark ignition, we can use compression ratios comparable with gasoline engine practice, that is, from 5.7 to 1 to 6 to 1. This lets us retain and use with perfect safety the same main parts such as crankcase, crankshaft, rods, etc., as we use on gasoline engines of the same displacement.

The same easy starting is also retained as on gasoline engines, cranking by hand being perfectly practical even in winter operation up to 6½ and 7-in bore. No auxiliary gasoline engine is required. To facilitate starting, a very small amount of gasoline is sprayed into the air inlet manifold just before cranking, and, as the heavy fuel is injected by the fuel pump, the engine begins to operate on it immediately.

Compression and maximum pressures are comparable with gasoline engine practice for similar size engines and can not rise to dangerous pressures as in compression ignition Diesel engines when starting at low atmospheric temperatures in the hands of unskilled operators or with unfavorable fuels.

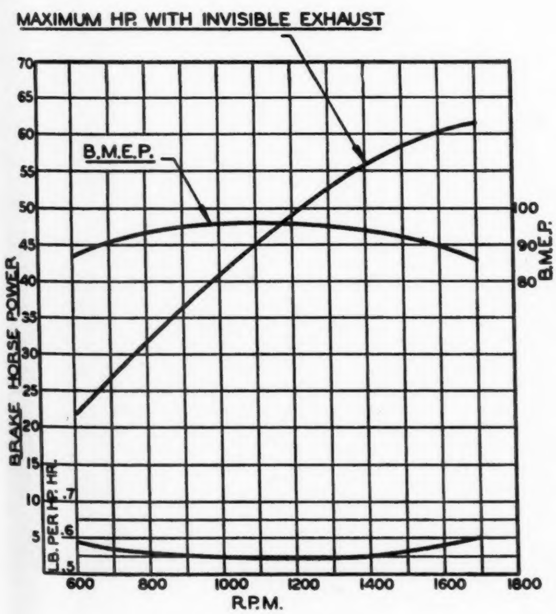



FIG. 5

There is no dilution of the lubricating oil whatsoever; in fact, the oil tends to become slightly heavier as in Diesel engine practice.

To keep clear the distinction in operation between a Diesel engine and the engine under discussion, we are suggesting a new terminology for these types. We refer to Diesel engines as compression-ignition injection engines and to the Hesselman engines as spark-ignition injection engines. Diesel and Hesselman have both been outstanding scientists and engineers, but there is nothing in their names that describe the engine cycles referred to.

Hesselman specialized for many years in the design and refinement of Diesel engines and controls a number of important Diesel engine patents. The more he got into the development of small Diesel engines the more he realized the seriousness of his fundamental problem, namely, excessive heat losses to the cylinder walls on the compression stroke. It was to overcome this that led to his development of the spark-ignition injection engine.

With the spark-ignition injection engine, the air is metered to keep the proper ratio of air to fuel. As in any engine where the air is throttled at part loads, more fuel is used per horsepower than at full loads but far less than on a carbureted engine due to excellent vaporization at light loads, for high turbulance still persists even at light loads. A cross section of this type of engine is shown in Fig. 4, showing the tangential inlet port, also the location of the spark plug and injector on opposite sides of the cylinder. In larger engines where wet sleeves are desired, the spark plugs and injectors are mounted at convenient angles in the cylinder head. This permits the tractor engine manufacturer's retaining practically all of his gasoline engine parts, except the head and piston, in making a conversion—with decided advantage from a service standpoint.

The air valve is interconnected to the fuel pump with suitable linkage to give the desired air-fuel ratio at all times. The conventional type of governor can be used to control the engine speed.

A typical performance curve is shown in Fig. 5. Note that the economy in the usual operating range from half load to full load is comparable to compression-ignition injection engines. The brake mean effective pressure has not been sacrificed as in carbureted kerosene or distillate engines to obtain this power. Brake mean effective pressures up to 110 lb have been secured in this type of engine with clean exhaust. On small six-cylinder bus and truck engines speeds up to 3000 rpm are used in daily operation.

Over five hundred of these engines from 3¾-in to 6½-in bore of American manufacture are in operation in five countries in Europe and are competing most successfully against European compression-ignition engines. They are in operation in this country in tractors, shovels, boats, air compressors, generating sets, and miscellaneous power plants. They permit of the generating of electric current in small quantities of 50 to 75 kw (kilowatts) at 0.75 cent per kilowatt-hour, without excessively heavy initial investments and with a wide range of fuels.

The German tar oil previously referred to which could not be burned in any Diesel engine on the market burns perfectly in this engine. Kerosene, distillates, alcohol, and similar fuels of proper viscosity can be used. Soy bean oil, although as now made is too viscous, offers promise as a suitable fuel for this engine as soon as the refiners can overcome the objection of viscosity. Nos. 1, 2, and 3 domestic heating oils can also be used.

Fuel costs for a medium-sized tractor with an engine of 4½-in bore by 5¼-in stroke in actual field operation indicate that savings in fuel costs of 70 per cent are easily

possible. This is based on gasoline retailing at 12 cents a gallon and fuel oil at $5\frac{1}{2}$ cents a gallon.

The power availability is much better than in a carbureted engine. By power availability we mean the quickness with which the engine responds to sudden and imperative demands for increased power. A carbureted engine operating at quarter of half load is often killed if increased loads are applied too abruptly. An injection engine is more responsive in this respect, as there is not the lag between the time the throttle is opened and when increased power is delivered to the flywheel. Any of you who have ever driven a tractor equipped with a carbureted engine and then an injection engine have been struck by this improvement in power availability. It results in increased capacity in the day's operation. It has been quickly appreciated by drivers of trucks equipped with injection engines—they are very enthusiastic in their evaluation of its power as compared with gasoline engines of the same displacement.

We recently sold a manufacturer of shovels a four-cylinder, spark ignition, injection engine of 334 cu in displacement for mounting on a shovel where a six-cylinder gasoline engine of 358 cu in displacement had been used. We did this with considerable misgiving due to the disparity in displacement and knowing that the four-cylinder engine had less power than the six-cylinder engine, even at the increased speed at which it was run. The operator of this shovel stoutly maintains it has far more power than duplicate shovels in the same operation using the six-cylinder engine.

In conclusion, I wish once more to emphasize the main problems encountered with small, compression-ignition injection engines, namely, the difficulty of conserving the heat of compression in small engines, and their greater susceptibility to variations in fuel than their larger brothers. These are basic problems that can not be overcome by later compromises in design, or by hanging on the engine preheaters, special types of injection systems, or similar devices. On some types of compression-ignition engines, this problem has been met by using a very compact combustion chamber and deliberately insulating this chamber from the cylinder head to conserve the heat from the previous power stroke as an aid to shortening the ignition delay. This is done in the Comet type of compression-ignition engine, and a marked improvement in combustion and smooth running results. The pressure and temperature in the cup are very much higher than the pressure out over the piston, due to picking up the heat from the very hot walls.

A glow plug is used in the Comet compression-ignition engine to facilitate cold starting, the glowing plug providing just the additional temperature needed to start combustion with a cold engine. The glow plug is heated by the battery for a few seconds before starting, and it is then switched off until it is again needed. It is, however, not needed for starting if the engine is thoroughly warmed up.

It is not practical to carry around batteries on tractors and many types of industrial equipment, and it is certainly desirable to retain the certainty and ease of hand starting that has always been associated with gasoline tractors. This can be assured with spark-ignition injection engines.

Probably no single factor has done more to advance the modern car, truck, or tractor to its present status than the dependability of its power plant, and the sole reason that hundreds of tractors are standing idle in the farm yards now and have been for the past three years has been the cost of fuel. Our aim should be to retain the enviable record of dependability set up by the gasoline engine and combine with it the fuel economies possible with injection engines.

# Soil Heating Design Curves

By Neal D. Herrick[1]

RURAL SERVICE engineers, who are called upon to design soil-heating installations, will find the accompanying curves a real time saver. Due to the wide variety of shapes of propagating benches in greenhouses, the rural development division of the company with which the writer is associated, found that, in order to give a prospective customer an answer as to the probable cost of equipment, considerable calculation was necessary. This hesitancy did not decrease the prospect's fear that it was "all guess-work anyhow."

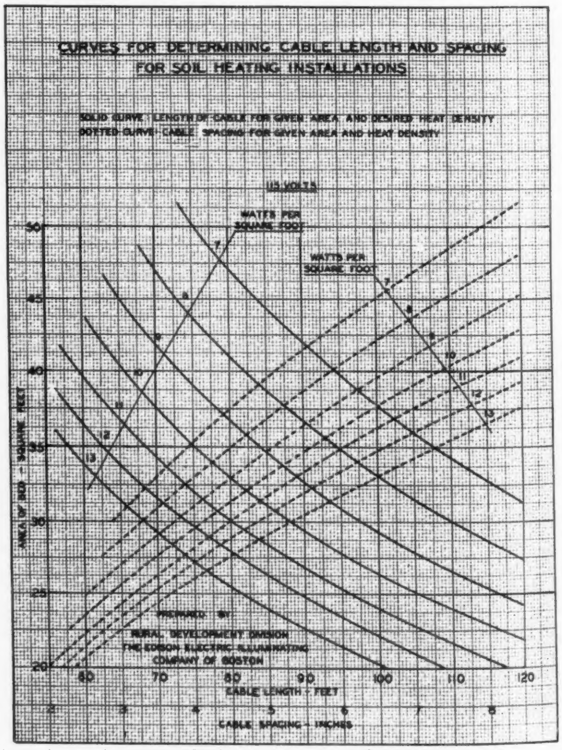
Other factors entering into successful design could not adequately be taken into consideration in a hurried calculation. The auxiliary heat conditions and the desired temperature rise, together with the type of plant being propagated, are factors to be considered.

The use of the curves makes it possible to immediately determine the length of cable necessary and the spacing of this cable in the bed, after the heat density per square foot has been decided upon.

Let us take the following example to illustrate the use of these curves:

A propagating bench has an area of 40 sq ft; 9 watts per square foot is the desired heat density. Follow along the 40 sq ft area line to the solid curve for 9 watts per square foot. Then drop down to a cable length of 73 ft. Continue along the 40 sq ft area line to the dotted curve for 9 watts per square foot. Then drop down to a cable spacing of 6.6 in.

[1]Sales engineer, Edison Electric Illuminating Company of Boston. Assoc. Mem. A.S.A.E.



# Corn Harvesting Methods in Connecticut[1]

By W. H. McPheters[2]

THE MOST COMMON method of cutting ensilage corn by the average dairy farmer in Connecticut is with a type of corn knife that is similar to a sickle. Before the development of this type of knife, corn was cut with the regular grass sickle. Of course, some of the larger farms now use the corn harvester, but the average small dairy farmer who has only a few acres of corn cannot afford to own a corn binder for a few days work a year. So he has clung to the corn knife. Since he knows of no better method, I believe he is right in doing so with the small patches of corn on steep hillsides. The situation is quite different in the corn belt where fields are much larger and the land much better suited to the use of the corn binder.

A few years ago the corn borer got into the state and has caused much thought to be given to its control. The knowledge that the corn borer winters over in the worm stage in the corn stalks and many other plants has caused the development of three mechanical methods of control. The borer can be killed by putting the corn up as ensilage. It is necessary to cut the corn nearly flush with the ground. By so doing most of the borers are destroyed as they have not been found to stay in the roots. This method, of course, means low cutting for good control because some of the borers may winter in the stubble.

The second method of control is to plow under completely all stalks and trash in the field either in the late fall or early spring. By so doing the borer perishes in the soil or comes to the surface and perishes, or is picked up by birds.

Many farmers do not like to plow in the fall due to erosion of the soil on steep hilly land (most of the land in Connecticut is rather steep hillsides), and quite frequently are unable to get the spring plowing done, due to weather conditions, before the borers emerge as moths in the spring.

Since it is difficult to get everyone to plow all stalks under at the proper time, it seems advisable to cut the corn flush with the ground. This gives fair control, even if the grower does not plow at the proper time.

A third method is to burn all stalks and trash. This is poor practice, as the humus is needed in the soil.

[1]Paper presented at a meeting of the North Atlantic Section of the American Society of Agricultural Engineers held at Harrisburg, Pennsylvania, January 1934.

[2]Agricultural engineer, Connecticut State College. Mem. A.S.A.E.

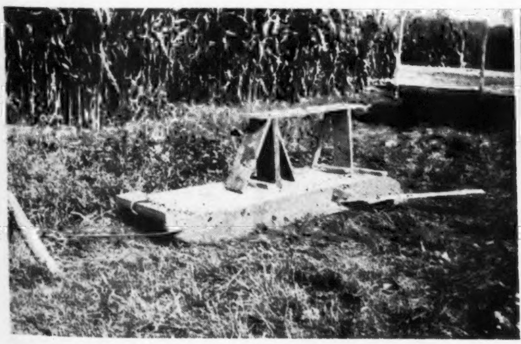
Knowing these methods of control the U.S.D.A. corn borer control office at Norwalk, Connecticut, did much work on plowing demonstrations showing methods of completely covering trash. The Norwalk office also developed a low-cutting attachment for the corn binder and demonstrated its use. The use of the binder is limited in Connecticut, so to meet the need of the small farmer they developed a short-handled hoe for cutting corn flush with the ground. This is replacing the knife to quite an extent, but many still cling to the corn knife, although it is not practicable to cut very low with it.

Two years ago last fall I came to Connecticut to take up the work as agricultural engineer with the Connecticut State College. This was about corn harvesting time, so I had the privilege of attending and helping with three demonstrations put on jointly by the U.S.D.A. corn borer control office at Norwalk and the farm management department of the state college. These were held on three different farms in three counties. They consisted of cutting corn with the low attachment on the binder, the use of the short-handled hoe, the plowing under of all trash, and the use of the low wagon for hauling ensilage corn. The farm management department was demonstrating the use of the low wagon as an efficient method of hauling the corn to the silage cutter.

This was my first introduction to corn borer control methods. Being confronted with the problem I have given it considerable thought since that time and have done some work in developing a small power method of cutting the corn flush with the ground.

Being familiar with the corn sled used in the Southwest gave me the idea of developing a similar sled for use in cutting ensilage corn in Connecticut.

The sled used in the corn belt cuts the stubble the height of the sled, the horse stops opposite each corn shock, the corn is carried to the shock, and so on. That is, the corn is carried in bundles and the sled is stopped at each shock for unloading. This method of course would not be satisfactory for cutting ensilage corn. While visiting the U.S.D.A. corn borer laboratory at Norwalk, I noticed a sled with a knife attached on the bottom of each runner. I was told that this was developed to cut old corn stalks for raking and burning. This gave me the idea of developing the low-cutting attachment on the sled for cutting silage corn.



(LEFT) THE CONNECTICUT CORN SLED WITH TEMPORARY SEAT. (RIGHT) THE LOW TRAILER CONNECTED WITH THE BACK END OF A TRUCK

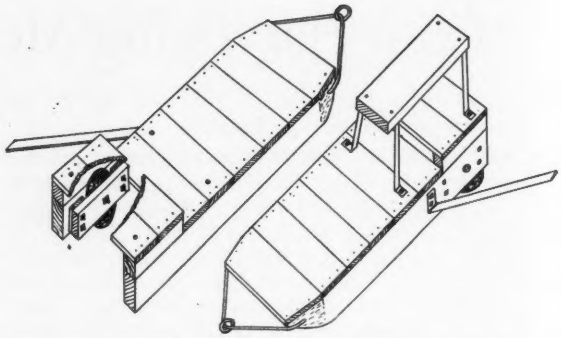
## THE CORN SLED

As a result of these demonstrations a sled was built and tried out. It was not wholly successful at first, it being impossible to get the corn off in neat bundles without stopping the horse. The first trial was with a knife on each side of the sled for cutting two rows at a time. The corn was cut flush with the ground and held until a fair size bundle was collected. Then the bundle was let fall straight backwards. The corn would not fall in bundles, but fell in a loose condition, and the men were in each other's way. So one knife was taken off and one row tried, with similar results. Then a method of laying the corn on the sled and stopping the horse at intervals to unload was tried out. This method did not seem good either. Finally the method of letting the corn fall at right angles to the row just back of the sled was tried out with fair success. This method seemed so promising that it was tried out with the man standing on the rear end of the sled, also sitting flat on the sled, and with a seat on the sled. All three methods were fairly successful.

The standing method was not so good because the operator would lose his balance and fall off. The method with the seat was good for fairly tall corn, but for low corn the method of sitting flat on the sled seemed to be best. Corn leaning over could also be handled a little better by this method. However, none of the methods can be very successful where the corn is badly blown down. During the fall of 1932 an old plowshare was used on the back end of the sled runner to keep the sled from being pushed away from the corn row. This caused considerable draft and as a result the horse was not able to pull the sled easily, and walked too fast, that is, with a jerky motion. During the fall of 1933 a rolling coulter was substituted for the old plowshare. This lessened the draft and was quite an improvement.

The rolling coulter method is a little more difficult for the farmer to attach satisfactorily, so still another method will be tried out next year. It will be a long blade tapering from no depth near the front end of the sled runner to about three inches below the bottom of the sled runner at the back end. Although the corn can be laid in fairly neat bundles, out of the way of the sleds, cutting the next row is not completely perfected as yet. I feel that it can still be improved. It has been demonstrated during the falls of 1932 and 1933 to about 700 farmers with the explanation that it is still being improved on.

At every demonstration the farmers were asked to make suggestions and criticisms. So by this means some good ideas were brought up to try out. As a general rule the farmers saw the possibilities of its use, and I feel sure some have tried one out this fall, but so far we have no record,



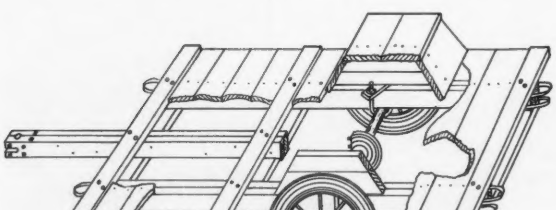
TWO VIEWS OF THE CORN SLED TO SHOW HOW THE COULTER IS FASTENED ON AND ALSO TO SHOW THE SEAT AND THE KNIFE

because the sleds would have had to be constructed since our late demonstrations.

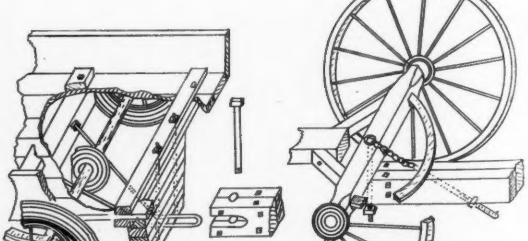
With the low wagon at one demonstration it occurred to me to try loading directly from the sled to the wagon rather than letting the corn fall on the ground. This was tried out with fair success at first. Since then several other trials have been made, but all trials were conducted under a handicap of corn that was badly blown down. When the corn was reasonably straight, only one trial was made and the corn was loaded very successfully.

So now it seems very probable that by another year we will be loading the corn on the wagon from the sled. In heavy corn I feel sure two men will be needed on the wagon to place it. So far no satisfactory way has been found to keep the sled from being pushed too far under the wagon when the man's weight is removed from the sled. The edge of the wagon serves for the seat. Weights placed on the sled served fairly well but were not as good as the man's own weight on the sled. Other methods were tried out, but none of them proved entirely satisfactory. A method of standing on the edge of the sled was tried out but it, too, has disadvantages. In spite of all the drawbacks the thing looks promising, and no doubt by another year some method will be developed that will be worth while.

The sled is constructed of two runners about five feet long made of either 2x6 or 3x6-in material, planked over similar to any sled. The knife is placed about 18 in from the back end and about one inch above the bottom of the runner. It was necessary to try a number of positions for the knife before finding a satisfactory one. The knife is given an angle of about 40 deg to the sled. The sled is



A VIEW OF THE LOW TRAILER SHOWING THE FRAMEWORK, HOW IT IS FASTENED TO THE WHEELS, AND THE PLANKS WHICH FORM THE TRAILER BED



THIS VIEW SHOWS THE HITCH AS USED WITH BOTH THE TRAILER AND THE FRONT WHEELS OF THE WAGON

pulled by one horse. The most satisfactory width tried out for the sled is 26 to 28 in. If the sled is too wide it is difficult to go between the butts of the bundles and the next row of corn. If it is too narrow, the horse has to walk too close to the row of corn.

As the sled must run very close to the row, it is necessary for the hitch to be made of an iron rod bent in the form of a half circle or a V, so that the front end of the sled will not hook into the row of corn. It is found that some sort of fin or rolling coulter must be placed on the side of the sled runner at the back end so that the knife cutting the corn will not push the sled away from the row. The rolling coulter causes much less draft than the fin, which was an old plowshare on the sled that was used. A long, gradual sloping type of fin will be tried out before the completion of all tests. The short, steep sloping fin catches trash and causes trouble, and the rolling coulter is more difficult for the average farmer to construct.

The sled can now be constructed for about $5.00, and if made to work satisfactorily will no doubt be accepted by the farmer, for he will be more than glad to give up the old corn knife method for a power method within his means.

### THE LOW WAGON

A great many of the Connecticut farmers have formerly been in the habit of hauling silage corn on high-wheel dump carts, and others use a flat frame on the regular wagon. With both types of wagon a man is required on the wagon to place the corn. That means the bundles must be handed to a man on the wagon. This is very inefficient. With the dump cart only small loads can be hauled because the corn is laid lengthwise the bed and piled high between pole standards on the side of the box.

The box on this cart is about half the length of the regular wagon box. It is supported by two high wheels. In front of the box is a driver's seat. Underneath the step or footrest a large kingpin fastens it to the front wheels. The front wheels are much lower than the rear wheels that support the bed. This permits the cart to be turned very short. So it is really convenient for general use about the farm, but is not efficient for hauling silage corn.

In order to induce the farmer to use a more efficient method of hauling silage corn, the farm management department of the Connecticut State College put on a series of demonstrations on the construction and use of the low wagon for hauling silage corn. At these demonstrations the time of loading and unloading was recorded for the various types of wagons. After sufficient trials were made the average saving of man-hour labor for loading on the low wagon was more than 50 per cent over the loading for the high wagon, and the work was no more difficult. The time required for unloading was the same for both high and low wagon.

The low wagon is a flat frame hung on the under side of the axles of a regular high-wheel wagon. Both front wheels and rear wheels project beyond the flat frame. This makes a long wagon which requires a lot of room for turning. Although awkward for turning it served the purpose of determining the efficiency of loading and unloading silage corn. The flat frame is only about 18 in above the ground. The height of the finished load is very little if any higher than the empty cart mentioned above. Two men load the wagon from the ground. No one is needed on the wagon for placing the bundles. The average time for two men loading about one and one-fourth tons of silage was about seven minutes. The load is removed from the wagon by two men standing on the ground, one on each side of the bundle carrier on the silage cutter. They place bundles in the carrier alternately. No one is needed on the wagon. By this method of handling silage corn one man is needed at the cutter and one extra man in the field, and a driver for each wagon. I attended three of these demonstrations shortly after coming to Connecticut. It was at these demonstrations that I became interested in this method, and since then have been cooperating with the farm management department in developing a type of low wagon that will be more convenient to use than the awkward, long, underslung frame. As a result we now have a very satisfactory low trailer that can be hitched to the back end of an old car or a truck, or can be attached to the front wheels of a wagon, thus forming a low wagon.

The trailer is made by using the rear wheels of a discarded automobile. The wheels are placed six feet from the rear end of the flat bed and eight feet from the front end. The width of the flat frame may be seven or eight feet. A heavy tongue about four feet long projects from the middle of the front end of the frame. It is so arranged that it can be hitched to the back end of a truck or to the front wheels of a wagon. This combination hitch enables the farmer to put the trailer to many uses on the farm. Due to the fact that the trailer is only about 18 inches high and has a large flat area, it is a very serviceable wagon to have on the farm.

EDITOR'S NOTE: The author will furnish on request detailed instructions for building the low trailer described in the foregoing paper.

# Electric Soil Sterilization

GROWERS sustain many thousands of dollars worth of loss each year due to bacterial and spore diseases of plants and to such insect pests as nematodes. Another and almost equally important factor is the loss due to the growth of weed seeds which are present in practically all soils. In the past very costly steam boiler and piping installations have been about the only effective means for sterilizing the soil and controlling the diseases, pests, and weeds.

Two electrical methods have now been devised. One makes use of heating elements immersed in the soil, and the other makes use of the principle that an electric current passed between metal plates in the soil will cause the soil to heat. Both types of heating arrangements have been used successfully in special soil-sterilizing boxes.

A new development has been worked out at the University of Maryland for sterilizing soils in place in the beds and benches of greenhouses. This method makes use of the resistance heating principle of passing an electric current through the soil. The development is still in the experimental stage, but sufficient progress has been made to indicate its practicability.

The cost of electric sterilization of soil compares favorably with the cost of steam sterilization. The electric process has been much more effective in sterilizing the soil to the bottom and corners of the beds than the older steam process. The labor requirements for electric sterilization are only a small fraction of those involved in the steaming process.—Geo. W. Kable before a meeting of the A.S.A.E. North Atlantic Section at Harrisburg, Pa.

# Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture.

DEVELOPMENTS IN REINFORCED BRICK MASONRY, *J. H. Hansen*. Amer. Soc. Civ. Engin. Proc., 59 (1933), No. 3, pp. 407-427, figs. 4. This paper contains a brief history of the development of reinforced brick masonry to the time that engineers in the United States became interested in the subject. Its development in this country is then given in detail by analysis of tests.

The author concludes, in view of the available evidence, that the assumptions accepted in the design of reinforced concrete structures can be used in the design of reinforced brick masonry items similar to those discussed. The recommended working stress of 0.4 $f_c$ given by the Joint Committee on Standard Specifications for Reinforced Concrete can be safely allowed on reinforced brick masonry. This would allow approximately 750 lb for cement mortar-brick masonry and 500 lb when cement-lime mortar is used, based on tests of full-sized wall panels.

The use of smaller bars (0.5 in round) is more feasible and will result in higher bond strength. Bond stresses should be limited to 80 lb per square inch. Shear stresses should be limited to from 25 to 30 lb per square inch, which would necessitate stirrups or bent-up bars in most beams. To develop maximum strength the reinforcing rods should be placed in vertical joints. The face of the brick that develops the greatest compressive strength should be placed normal to the line of compressive stress in the beam. The value of the ratio $E_s/E_b$ is somewhere between 20 and 30. The mortar should consist of 1 part cement, 0.25 part lime, and 3 parts sand, by volume. Builders should adhere rigidly to all the requirements of good brick masonry, that is, the proper wetting of the brick and complete filling of joints.

TESTS OF RIVETED AND WELDED STEEL COLUMNS, *W. A. Slater* and *M. O. Fuller*. Amer. Soc. Civ. Engin. Proc., 58 (1932), No. 7, pp. 1147-1180, figs. 22. Tests conducted at Lehigh University are reported which were undertaken to procure a comparison of the behavior and strength of built-up steel columns fabricated by riveting, with similar columns fabricated by welding. The program included 9 columns, of which two were riveted and seven were welded. In four of the welded columns the welding was continuous throughout the length. In the other three welded columns intermittent or stitch welding was used. The lengths to the nearest inch were 19 ft 8 in for three of the columns, 16 ft 6 in for two, 15 ft 5 in for three, and 5 ft 6 in for one.

The columns were built up by riveting or welding cover plates to the H-section or the I-section which formed the core. The total cross sectional area ranged from 14.26 to 24.3 sq in in different columns. All were tested as flat-ended columns. Observations included measurement of strains, slip of plates, deflection of column due to the applied load, and strains caused by plastic flow of the heated metal and by the stress set up when the heated metal cooled. In general, the strains were measured in various positions in cross sections at the top, middle, and bottom of the column. A special feature was the testing of the column having an excessive initial curvature for comparison of strength, bending moment, and deflection, with those of a similar straight column.

The largest slipping of plates observed was about 0.01 in. No weaknesses attributable to slipping of plates developed. Stitch welding caused shortening of the metal at sections through the welds and elongation at the edges of the cover plates at sections midway between welds.

The points of first appearance of strain lines corresponded in position to the points of highest stress due to heating of the metal, insofar as the stress due to heating could be determined. The average modulus of elasticity determined from the coupon tests was 29,300,000 lb per square inch, and that determined in the tests of the columns was 28,650,000 lb per square inch. The modulus used in computing stress from strain was 29,000,000 lb per square inch. In all comparable cases the deflections were greatest for the continuously welded columns. There was little distinction as to deflection between the riveted and the stitch-welded columns. In general, the magnitude of the deflection corresponded to the magnitude of the initial departures from straightness. Nothing in the tests indicated any marked advantage of either riveted or welded columns over the other as far as freedom from bending moments is concerned, although the continuously welded columns seemed to be more subject than the others to initial deflection.

The ratios of the stress at maximum load to the yield-point stress determined from the coupons were so nearly equal for all the columns tested that no reliable distinction can be made between the merits of riveting or welding columns, either with a continuous or an intermittent weld. Although the tests indicated the presence of initial stresses of considerable magnitude, introduced in the cooling after welding and probably after rolling also, the maximum loads carried did not appear to be appreciably influenced thereby.

STANDARD EQUIPMENT FOR EVAPORATING STATIONS. Amer. Soc. Civ. Engin. Proc., 59 (1933), No. 2, pp. 266-268). The recommendations of the Special Committee on Irrigation Hydraulics of the American Society of Civil Engineers regarding standard equipment at evaporation stations, operated primarily to determine the evaporation from large water surfaces in the immediate neighborhood, are presented.

SOIL EROSION: CAUSES AND METHODS OF CONTROL, *H. B. Roe*. Minn. Univ. Agr. Ext. Spec. Bul. 160 (1933), pp. 24, figs. 24. Practical information is presented on the subject. It has been found that sheet erosion is the most harmful type, and that the important contributing causes of erosion are certain current farming practices. The ultimate method of sheet erosion control is that of terracing practically all cropped slopes subject to erosion, coupled with cover cropping and contour cultivation. The best type of terrace for general use is considered to be the standard graded Mangum terrace. Crop rows may be run diagonally across the terraces, but contour planting and cultivation approximately parallel to the terraces are an effective aid in controlling sheet erosion, and are recommended.

COMPARISON OF A TRENCH SILO WITH AN UPRIGHT SILO, *J. R. Dawson* and *A. G. Van Horn*. U. S. Dept. Agr. Circ. 274 (1933), pp. 16, figs. 4. Tests conducted for two seasons by the U.S.D.A. Bureau of Dairy Industry in cooperation with the Oklahoma Agricultural and Mechanical College to determine the relative merits of the trench and the upright silo are reported. The trench silo used was 71 ft long, 6 ft 9 in deep, 14 ft wide at the ground level, and 10 ft wide at the bottom. At each end of the trench the bottom sloped upward, forming a gradual incline to the ground level. The capacity of the trench was approximately 4,460 cu ft. The upright silo used was of tile-block construction and was 14 ft in diameter and 22 ft deep. It was of the semipit type, having 11 ft of its depth below and 11 ft above the ground level.

The cost of constructing the trench silo was $1.78 per 100 cu ft of capacity, practically all of which was for team and man labor. The original cost of material and construction of the upright silo was $10.82 per 100 cu ft of volume.

It was found that the upright silo is markedly superior to the trench silo in preserving silage. On the basis of the average losses during the two years' experiment it may be expected that 78 out of every 100 tons of material placed in the trench silo can be recovered as edible silage, and 9.2 tons of the 22-ton loss will be the result of spoilage. In the upright silo, 88 tons out of every 100 tons of material ensiled can be recovered as edible silage, and 6.5 tons of the 12-ton loss will be the result of spoilage. The spoiled silage in the trench silo was largely along the walls of the trench. The quality of edible silage from both silos was excellent.

The average weight of a cubic foot of silage under the conditions of the experiment was 29.6 lb for the trench silo and 34.5 lb for the upright silo. The moisture content of the silage was practically the same for both silos. The weight per cubic foot of silage from the trench silo was considerably lower than similar weights for corn and kafir silage at other experiment stations.

The total cost of placing the crops in the silos from the cutter and removing the silage from the silos was $1.13 per ton of edible silage for the trench and $0.44 for the upright silo. However, the location of the trench and the methods and equipment employed will materially affect these costs. The cost of covering the silage and removing the cover from the trench is excessive, and is probably the most significant item of expense in trench silo operation.

A layer of straw together with from 12 to 16 in of soil as a covering is more efficient in preserving the silage than is straw alone.

EVAPORATION FROM RESERVOIR SURFACES, *R. Follansbee.* Amer. Soc. Civ. Engin. Proc., vol. 59 (1933), no. 2, pp. 254-265. This paper, a contribution from the U. S. Geological Survey, contains the results of all available evaporation records, not only in the United States and outlying possessions but also in foreign countries, reduced to reservoir surface evaporation by means of coefficients which are stated for each record. These results are given in summarized form, together with records of temperature, wind velocity, and relative humidity, so far as available. A total of 210 evaporation records are presented.

After the summary the relative effect of temperature, wind velocity, and relative humidity is shown by comparison between pairs of records in which two factors are the same and the third is widely different.

A brief discussion of the variation in evaporation throughout the United States concludes the paper.

EVAPORATION FROM DIFFERENT TYPES OF PANS, *C. Rohwer.* Amer. Soc. Civ. Engin. Proc., vol. 59, (1933), no. 2, pp. 223-253, figs. 8. In a contribution from the Colorado Experiment Station, a summary of the results of the available records where a comparison has been made between the evaporation from different types of pans or between the evaporation from a pan and a large water surface under similar conditions is given, together with recommendations as to the best types of pan to use under different conditions and the procedure to be followed in taking the observations.

The data show that records from floating pans are not as consistent or reliable as land pan records, nor is the evaporation from a floating pan any nearer the evaporation from a large water surface than that from a sunken pan of the same size and shape.

Comparisons between the evaporation from class A land pans of the Weather Bureau (type 1) and Colorado sunken pans with the evaporation from large water surfaces indicate that there is a definite relation between the pan and the reservoir evaporation. For the class A land pan the factor for computing the reservoir evaporation from the pan evaporation is between 0.69 and 0.70, and for the Colorado pan it is 0.78. Comparison of the evaporation from different types of pans with that from large water surfaces of different sizes shows that the size of the pan has a proportionately smaller effect on the evaporation as the size of the surface increases, and that when the diameter is greater than 12 ft the size of the pan has practically no effect on the evaporation.

When all factors are considered pan 1 is probably better suited for evaporation investigations than the other evaporation pans. In order to obtain comparable evaporation results standard equipment installed under representative conditions should be used, and a standard procedure should be followed in making the observations.

An appendix summarizes data on evaporation from water surfaces.

HOME REFRIGERATION METHODS IN RURAL RHODE ISLAND, *B. M. Kuschke* and *M. Whittemore.* Rhode Island Sta. Bul. 239 (1933), pp. 19, figs. 3. The results of a survey of the types and efficiencies of refrigeration methods used in rural Rhode Island are presented, together with the results of laboratory tests of different types of new refrigerators.

The data obtained emphasize the fact that the use of a spring, cellar, or well is not to be recommended as a safe method for storing perishable food, such as milk, meats, and meat broths.

Although the temperatures maintained by ice refrigerators appear somewhat high, there is considered to be no doubt that this method may be thoroughly satisfactory if the right equipment is selected. While efficient ice chests and refrigerators are being made at a very moderate cost, the long life of the ice refrigerator as shown by the data reported seems to justify a reasonable investment.

The mechanical refrigerator furnishes most desirable and adequate food storage temperatures. The initial cost seems high. If, however, the life of the equipment proves to be a reasonable number of years, and the maintenance expense is low, then the mechanical refrigerator will prove a good investment, as more satisfaction, convenience, and health protection may be obtained by the mechanical method than any other.

Very satisfactory results were obtained in the experiments with the kerosene operated refrigerator. The freezing of ice cubes and desserts was as well done as in the electric refrigerator.

Suggestions for selecting a refrigerator are included.

CROSS-BLOCKING SUGAR BEETS BY MACHINE, *E. M. Mervine* and *A. W. Skuderna.* U. S. Dept. Agr. Leaflet 97 (1933), pp. 6, figs. 6. This leaflet describes the machine set-ups by which sugar beets may be satisfactorily blocked by machine.

Field studies made in cooperation with the Colorado Experiment Station and the University of California under a wide variety of soil and plant growth conditions and with several types of blocking machines showed definitely that mechanical blocking may be substituted for hand blocking with the hoe, provided initial stands are adequate and the work is carefully done so as to prevent injury to the stand.

In its simplest form a cross-blocking machine is an ordinary beet cultivator with cultivator tools so spaced that blocks of plants of the desired size and spacing are left undisturbed when the cultivator is drawn crosswise of the beet rows. Where no unusual conditions exist, knife weeders (knives) may be used for blocking. These should be so spaced on the tool bar that they will leave blocks of the desired size. A greater range of adjustment may be had by allowing the knives to overlap. It is desirable to have the knives staggered to make them self-cleaning and to throw soil toward the blocks rather than away from them. In extremely loose or trashy soil where knives have a tendency to push the soil and to tear small plants from their blocks, it is desirable to use disks. If the soil is in good tilth and free from trash, duckfeet will do good work. The blades of the duckfeet should be flat, and hence lessen the danger of covering the beets in the blocks. Any one of several sizes of duckfeet may be used, depending on the type of soil to be cultivated.

A method is presented for improving the stand of cross-blocked beets.

HEAT TRANSFER THROUGH STAINLESS STEEL AND GLASS-LINED STEEL IN DAIRY PASTEURIZERS, *J. C. Marquardt, W. D. Pheteplace, Jr.,* and *A. C. Dahlberg.* New York State Sta. Tech. Bul. 211 (1933), pp. 25, figs. 11. A study is reported of the heat transfer values of two materials commonly used in the construction of pasteurizing vats. The heat transfer coefficients were correlated with metal, film, and milk temperatures as related to type and temperature of the heating medium and the rate of agitation.

Comparisons of the heat transfer coefficients were possible as the tests of the two materials were made under like conditions. It was found that the heat transfer coefficients covered a wide range when the materials were used under different conditions. Heat transfer was more rapid through 18-8 alloy steel than through glass-lined steel when used as linings for vat pasteurizers. When water at 210 deg F was used to heat milk, the coefficient of heat transfer for the steel was 91.7 and for glass-lined steel 73.2. Increasing the speed of the propeller agitator increased the heat transfer up to a certain speed above which there was no increase but an actual decrease.

Water, skim milk, milk, and cream decreased the rate of heat transfer in the order given. The coefficient of heat transfer for water heated in 18-8 alloy steel was 15.7 greater than for milk, while in glass-lined steel the difference was 6.7. It is evident that water may be substituted for milk in testing pasteurizers for heat transfer if an allowance of approximately 10 to 20 per cent is made, depending upon the rate of heat transfer. The coefficient of heat transfer for cream was 17.9 less than for milk in 18-8 alloy steel and 9.9 less in glass-lined steel.

The temperature of the film of milk within 1/32 in of the metal was usually within 3 deg of the temperature of the milk, even though the metal was from 20 deg to 40 deg hotter than the milk and the heating water was 210 deg. Increased agitation slightly decreased the spread in temperature between the milk film and the milk. Since the use of flowing steam as the heating medium did not increase the rate of heating, it is evident that flowing steam would not produce a hotter metal lining than did boiling water.

The rate of transfer of heat through a given metal varies markedly with the conditions under which the tests are conducted. For example, a coefficient of heat transfer of 181 was secured for 18-8 alloy steel in a vat of a different design.

FIRE HAZARD OF DOMESTIC HEATING INSTALLATIONS, *G. Q. Voigt.* [U.S.] Bur. Standards Jour. Res., vol. 11 (1933), no. 3, pp. 353-372, pls. 2, figs. 7. Tests were conducted with stoves, furnaces, and their pipes, spaced at different distances from unprotected partitions, ceilings, and floors, and the maximum temperatures thereon measured in an attempt to determine by experimental means the fire hazard involved. Protections of sheet metal, asbestos, or brick were then applied and the closest distance determined that would be safe from the standpoint of ignition of the wood.

It was found that stoves for house heating should be spaced not less than 24 in from walls faced with wood. If bright sheet metal is applied to the walls the spacing can be decreased to 12 in. Similarly, plastered wood stud partitions, while requiring a spacing of not less than 18 in if unprotected, may be spaced at 9 in if bright sheet metal is applied.

If stoves are without ash pits or if ash pits are heated to near redness, an air space of 5 in or more was indicated as necessary between the stove and a wood floor in addition to 0.25 in thick incombustible insulation applied under sheet metal over the exposed portion of the floor. With the *(Continued on page 150)*

# AGRICULTURAL ENGINEERING

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## Engines and Fuels for Agriculture

TO APPRAISE the significance of engines and fuels—represented by several papers in these pages—we must, despite the limitations implied in our Society name, look beyond the boundaries of America and of agriculture. On the one hand, America, as the world's leading maker of farming equipment, must design engines for tractors, combines, and other uses which will most economically meet a variety of fuel situations (both as to cost and character) sharply different from those which prevail in our own borders.

And, both at home and abroad, our farm equipment industry is the principal producer of tractors for all manner of non-agricultural uses. In some of these applications the annual hours of operation are so high as to put more emphasis on fuel cost than in farm service. To some extent operating characteristics may take on different importance.

Within the domestic field for farm tractors, the evolution of row-crop tractors through about the same period as the development of fuel ratings by octane numbers, classification of fuels thereunder, and the commercial production of fuels with high anti-knock value has given opportunity and incentive for one type of special adaptation of engine to fuel. For engines in which it is desired to use low-grade, low-cost fuels there is the same impetus toward accurate engineering of specialized design, both among carbureted and injection types. The omnivorous engine with its mediocre efficiency seems logically due for abandonment.

While alcohol or other farm-derived material still seems economically hopeless as basic engine fuel, persistent study shows some promise for such substances as minor, modifying ingredients in composite fuels. That such fuels thus far studied appear to deliver their best performance at low or moderate speeds, and at the higher load factors, points toward agricultural engines as their most feasible application. Though the prospects seem none too bright, the immensity of the market justifies continued research not only by our profession, but by all appropriate agencies having an interest in expanding the market for farm products.

While suggesting a continued gamble for these high stakes, let it be remembered that ethyl alcohol, though a symbol in the popular mind, is only one of many substances which the wizardry of organic chemistry may devise as by-products of industrial processes using farm crops, or, if their influence on the combustion of hydrocarbons and resulting engine efficiency is great enough, as primary products.

One direction of research which might be pushed further is the concurrent carburetion of substances which may be immiscible, or if misible may be used most efficiently in varying proportions to suit load factor or other governing conditions. While the complications of two fuels separately carbureted might be prohibitive in automotive practice, they would be less objectionable in tractor service, where many users already have used two fuels and a separate water feed.

We have now reached the point where it no longer is sufficient either to design engines for available fuels, or to perfect fuels for existing engines. Henceforth engine design and fuel development must get in step and go forward together. Such progress will involve scientists and specialists from sundry fields outside the strict scope of agricultural engineering. But, so far as engines for agriculture are concerned, their logical meeting place and proving ground are to be found in the deliberations and activities of our profession.

As such, even more than for the subject matter presented, the joint appearance of engine and fuel engineers at the last meeting of the A.S.A.E. Power and Machinery Division is significant.

## Irrigation Pumping

To the Editor:

I AM MUCH interested in the paper by Miss Farr and Dr. Gardner, entitled "Problems in the Design of Structures for Controlling Ground Water" in AGRICULTURAL ENGINEERING for December 1933.

The battery type of well suggested in this paper, and in the paper published earlier, by Eliason and Gardner, appears to be worthy of study for the possibility of economy in the development of water.

I do not think, however, that the assumption, made toward the end of the paper that for a single well in a large artesian basin $Q$ is proportional to $R_0$ when $H$ is held constant, is in keeping with Equation 12.

The case where $Q$ is permitted to vary and $H$ remains constant with the same assumption as to the constancy of $R$ used in the paper may be solved as follows:

Substituting in Equation 10 the value of $Q$ from Equation 12, we have

$$z = \frac{(a + cR_0)\ ln\ (R/R_0)}{CH} + PH + b \quad \text{.......} (17)$$

Differentiating, we have

$$\frac{dz}{dR_0} = \frac{l}{CH} \left( - \frac{a}{R_0} + C\ ln\ R - c - c\ ln\ R_0 \right) \quad \text{......} (18)$$

Equating to zero we have

$$c\ ln\ R_0 + a/R_0 = c\ ln\ R - C \quad \text{.......} (19)$$

This equation may be solved by the method of trial and error.

If we assume that the well costs represented by $a$ (Equation 10) total about \$1600, and interest and depreciation are taken as 20 per cent, you will have the value $10^{-5}$. Using this value for $a$, $4 \times 10^{-9}$ for $C_1$ as given, and 100,000 cm (3280 ft) for $R$, we find that the most economical well will have a radius of about 600 cm (20 ft). Reducing the value

of $R$ to 50,000 cm increases the value of $R_\circ$ to about 800 cm (27 ft). It should be borne in mind that the assumptions used in developing Equation 12 do not justify fixing any definite value of $R$. Experience in Southern Idaho and in Oregon indicates that values of one-half to three-quarters of a mile for $R$ are not unreasonable.

Tentative comparisons of the cost of developing water by the battery method and by small single wells seem to indicate that the latter method is slightly cheaper.

The difference in the conclusions as to the most economical diameter of wells drawn by Farr and Gardner in the paper under discussion and by myself in the paper in the November issue of AGRICULTURAL ENGINEERING is obviously due to the great difference in the rate of increase in cost of wells with increase in diameter for the two types of construction.

Obviously, the relative costs of energy for pumping and of equipment for the wells will be important in fixing the most economical values for $R_\circ$, $Q$, and $H$. Unfortunately, so far as I am aware, no complete solution of the problem taking into account both first and operating costs and considering all three factors as variables, has yet been offered.

Still another factor which enters into most irrigation and drainage pumping problems is the length of the pumping season. If Equation 10 is modified by substituting $A$ and $B$ in terms of dollars per year, respectively, for $a$ and $c$ which are in dollars per second, a new term, $T$, equal to the number of seconds of pumping per year, is inserted, and the value of $H$ from Equation 12 is substituted, we have

$$2 = \frac{A + B R_\circ}{QT} + \frac{PQ \ln R/R_\circ}{C} + b$$

Differentiating and equating to zero for the case where $Q$ is held constant, and considering $T$ as a constant, we have

$$R_\circ = \frac{PQ^2 T}{c C}$$

From this it appears that the radius of the most economical well under these conditions varies directly with the length of time pumped each year.

These considerations appear to indicate that somewhat smaller wells will be more economical than those suggested in the paper, but do not in any way contradict the conclusion that well batteries should be given careful consideration.

The conclusion of the authors that tile drainage without relief of the artesian pressure by wells is not feasible under conditions similar to that described, is certainly confirmed by experience in other areas.

M. R. LEWIS

Irrigation engineer,
U.S.D.A. Bureau of Agricultural Engineering.

# NEWS

## SAE Tractor Meeting

A PROGRAM of particular interest to tractor engineers is being sponsored by the Tractor and Industrial Power Equipment Committee of the Society of Automotive Engineers, to be held at the Hotel Pfister, Milwaukee, Wisconsin, April 18 and 19. Members of the American Society of Agricultural Engineers have been cordially invited to attend this meeting.

The opening session of the meeting on Wednesday forenoon, April 18, will be devoted to the subject "The Relation of Engineering to Manufacturing and Merchandizing in the Farm Equipment Industry," and the principal speaker at this session will be Mr. Fowler McCormick of the International Harvester Company. The afternoon session of the same day will feature two topics. H. H. Howard of the Caterpillar Tractor Company will be the principal speaker on "Some Diesel Tractor Problems," and Mr. E. R. Jacobi of the Continental Motors Corporation will discuss "Spark-Ignition Engines for Agricultural and Industrial Use."

The evening session of the same day will be devoted to the subject "Research in Agriculture," at which the principal speaker will be Mr. S. H. McCrory, chief, Bureau of Agricultural Engineering, U. S. Department of Agriculture.

The morning session of the second day will feature the subject "Requirements of Tractor and Industrial Engines," the principal speaker being Mr. A. C. Staley of the Chrysler Corporation. The closing session on the afternoon of the same day, will be devoted to a discussion of "The Agricultural and Industrial Engine Fuel Situation," the feature paper on this subject to be presented jointly by Mr. R. E. Wilson and Mr. D. P. Barnard of the Standard Oil Company of Indiana.

It is of special significance that the personnel of the SAE Tractor and Industrial Power Equipment Committee are, for the most part, members of the ASAE Committee on Agricultural and Industrial Engine Research; this group is giving special attention to problems of joint agricultural engineering and automotive engineering interest

## Kable Heads Farm Electric Survey

UNDER the immediate direction of George W. Kable, lately director of the National Rural Electric Project at College Park, Maryland, the federal government is making a rapid survey—initiated the middle of March and to be completed prior to May 1—to appraise the possibilities of supplying electric service to additional rural customers, and to gather data on present rural service and its utilization

The survey is being made by the U. S. Department of Agriculture on request of the Federal Power Commission, as a part of a general survey ordered by the President into power resources, transmission, distribution, utilization, etc., of electric power in the United States. It is set up as a continuation of the engineering phase of the Farm Housing Survey and as such is authorized through the Bureau of Home Economics. Under state supervising engineers the work is being done by county engineers in selected counties or districts previously covered by the housing survey. So far as it affords engineers qualified for electrification work, they (and clerical help) are drawn from housing survey personnel. Costs of the electrification survey are being handled through the CWA machinery.

Director Kable, however, is attached to the Bureau of Agricultural Engineering and from that angle is guiding the mapping of the selected areas to show existing and feasible lines and extensions, and the gathering of data on potential customers, not only farms but industries, stores, etc., which might be served from rural lines. Adequacy of power sources, conditions affecting construction costs, existing rate structures and policies, are among the information sought, all to determine the feasibility of accelerated rural electrification.

## New ASAE Members

*Frank F. Alexander*, sales manager, Electric Wheel Company, Quincy, Ill.

*Wm. Leverett Cummings*, sales promotion division, Frigidaire Corporation. (Mail) 40 Jane Road, Newton Center, Mass.

*Clarence E. Ghormley*, senior engineer, Wisconsin Industrial Commission, Bangor, Wis.

*Linwood D. McClure*, supervisor of retail and rural sales, Philadelphia Electric Company. (Mail) York Road and Summit Ave., Jenkintown, Pa.

*William F. Simpson*, foreman engineer, Kentucky State Forest Service, CCC Camp No. 63-P.E., Hardinsburg, Ky. (Mail) RFD No. 1, Smithfield, Ky.

## Applicants for Membership

*Don Critchfield*, trade promotion, Lead Industries Association. (Mail) 2535 P St., Lincoln, Nebr.

*John A. Schaller*, senior engineer, Erosion Control Division, Emergency Conservation Administration. (Mail) Barneveld, Wis.

## Agricultural Engineering Digest

*(Continued from page 141)*

firebox resting directly on the floor, temperatures high enough to cause ignition of wood were transmitted through a 4-in brick base.

Tests with smoke pipes indicated that a clearance of 12 in from ceiling or joists was adequate. Where smoke pipes pass through combustible partitions, either a ventilated air space of not less than 4 in, or 2 in of insulation all around the pipe, was found necessary.

Furnaces for hot water installations and their pipes were found to present little hazard to adjacent construction as fired with either coal, oil, or gas. The hazard from warm-air heating ducts was found to be moderate, protection being required only where they enter floors or partitions relatively close to the furnace. In the case of the pipeless furnace, the downdraft of cold air around the warm air-duct protects the adjacent construction, the hazard with this equipment resulting mainly from placing combustible materials on the warm-air register or locating the latter beneath or too close to partitions.

Tests with a gas range having an oven without insulation indicated that a 6-in separation between the side of the oven and a wood partition gives reasonably safe conditions.

A Method of Generating Electricity as a Greenhouse By-Product, *A. H. Senner.* Rural Electrif. and Electro-Farming, vol. 9 (1933), no. 100, pp. 114-116, fig. 1. In a brief contribution from the U.S.D.A. Bureau of Agricultural Engineering, a description is given of a scheme for producing electricity as a by-product of greenhouse operation. It consists primarily in raising the pressure of the steam-heating boiler above that required for heating and utilizing the steam for operating a turbine, using the exhaust for heating.

Data are presented to show that the total heat of steam at the various pressures above 14.7 lb per square inch absolute atmospheric pressure increases only a little more than 5 per cent even at 500 lb absolute, but the temperature on the Fahrenheit scale more than doubles. The back pressure turbine is considered to be the simplest means of obtaining by-product power from exhaust steam. A cost analysis is presented indicating that current can be generated in such a plant at a cost of 0.18 d (pence) per kilowatt-hour.

Causes and Prevention of Potato Tuber Defects at Harvest Time, *E. V. Hardenburg.* Amer. Potato Jour., vol. 10 (1933), no. 9, pp. 173-176. A field survey in New York at harvest on 101 farms in 1931 and on 137 in 1932 showed that on the average over 20 per cent of potato tubers as dug either have mechanical injury or physiological defects. About 9 per cent are bruised, while 4.3 per cent additional are skinned and cut by the digger. The data made evident that a crop harvested before complete maturity should be handled more carefully than one normally matured, since it is much more subject to bruising and skinning.

Most of the 13 types of machine diggers in operation on 161 farms in 15 New York counties in 1932 were of the chain elevator type, and all appeared capable of efficient work if operated and equipped properly. Wherever the digger caused much injury, the fault could have been largely remedied. Most bruising was due to too harsh contact of the tubers with the elevator chain rods, especially where the soil was dry and only a little was carried over the elevator. Diggers rigged with a continuous chain usually caused less injury than those carrying rear attachments. Other adjustments were indicated. Comparison on 247 farms showed more tuber injury caused by picking directly into bushel slatted crates than into split or wire stave baskets or tin buckets. With crates, the tendency is to throw the tubers farther than where baskets or buckets are used. Additional handling required in pouring the baskets into crates or buckets did not add materially to the total injury found.

Wood-Beam Design Method Promises Economies, *J. A. Newlin, G. E. Heck.* and *H. W. March.* Engin. News-Rec., vol. 110 (1933), no. 19, pp. 594-596, figs. 4. In a contribution from the U.S.D.A. Forest Service, a new design method for calculating the horizontal shear in wooden beams is described. It assumes that because of the shear distortion in the vicinity of the base of checks or fissures that are present in all beams, the upper and lower halves of the beam act to some extent as independent beams. The result is to relieve the mean shearing stress in the neutral plane. An attempt is made to explain the elastic behavior of a checked beam under load and thus to explain the discrepancy existing between the facts of experience and the predictions of the usual methods of calculating shear. The background for this explanation is furnished by an approximate mathematical analysis of the problem combined with the results of a series of about 200 tests, in which the loads causing shearing failure were observed on built-up artificially checked beams varying from 0.75 by 1.5 in to 8 by 16 in in cross section and with varying amounts of checking. On the basis of the theory and the results of *(Continued on page 152)*

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tests, practical directions are given for the more realistic calculation of loads that will cause shearing failure.

It was found that for checked beams with a span-depth ratio of 9 to 1 the point of application of the minimum concentrated load causing failure by shear is at a distance from the support approximately three times the height of the beam. The distance of the critical point from the support is somewhat greater for longer spans and somewhat less for shorter spans, but in any case for loads applied at three times the height of the beam from the support the two-beam portion of the reaction at the nearer support is approximately one sixth.

## EMPLOYMENT BULLETIN

**An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, for which members of the Society would be logical candidates, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available" section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested.**

### Men Available

ENGINEER, with varied experience in drainage, transportation, and civil engineering problems on sugar estates, also in estimating and appraising and in making industrial surveys and cost reports, and whose experience covers a long successful record in many sections of the United States and in the tropics, is seeking a new business connection. Has been with present employer ten years but desires to make a change if he can locate in any tropical section. MA245

ELECTRICAL ENGINEER, graduate of the University of London, desires employment as rural service engineer or distribution engineer with an electric power company, or as research engineer in rural electrification with an agricultural experiment station, preferably in eastern or western United States. Several years experience in rural electrification with electric power companies and in research at a state agricultural college. Age 33. MA246.

AGRICULTURAL ENGINEER, graduate of Michigan State College, at present working for master's degree at University of Minnesota (with major in farm power and machinery), desires employment with farm equipment manufacturer either in engineering or sales work. Born and reared on a farm. In connection with college work, he has served as teaching and research assistant, all the work being in farm machinery. Available April 1, 1934. MA247

AGRICULTURAL ENGINEER, graduate of Virginia Polytechnic Institute and licensed surveyor, with varied experience in surveying and construction work, and three years' carpentry experience, desires employment as surveyor or with construction company. Single. Age 27. Will go anywhere. MA248

AGRICULTURAL ENGINEER with both bachelor and master of science degrees (majoring in agricultural engineering) from midwest universities, two summers' experience as irrigation investigation engineer in midwest state, five years' experience with agricultural engineering department of large university where the duties consisted of research work in reclamation, farm development, land use study, and a regular teaching schedule mainly in reclamation, desires employment where qualifications meet the need, preferably with farm equipment company or in agricultural engineering with some state agricultural college. Married. Age 27. MA249

### Positions Open

AGRICULTURAL ENGINEERS capable and experienced in soil erosion control work will be interested in openings that give promise of shortly developing in connection with one of the new activities of the federal government. Job specifications furnished provide that applicants must be capable of formulating plans for soil erosion control and competent to assume responsibility for and supervision over the engineering phases of such work. Good engineering training combined with experience in the handling of drainage, hydraulic, and irrigation problems is essential. Experience in farming would be helpful. Applicants should have executive ability and be capable of handling men. It is possible that there will also be similar openings of a lesser grade with experience similar to the foregoing, except that less extensive and comprehensive experience would be required. PO101

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